Using Algae/primary producers to Support Nutrient Criteria Development

Midwest Surface Water Monitoring and Standards (SWiMS) Meeting

February 3, 2004

Julie A. Hambrook

USGS

Stillwater River near Union, Ohio

Selecting methods for developing nutrient criteria in rivers and streams

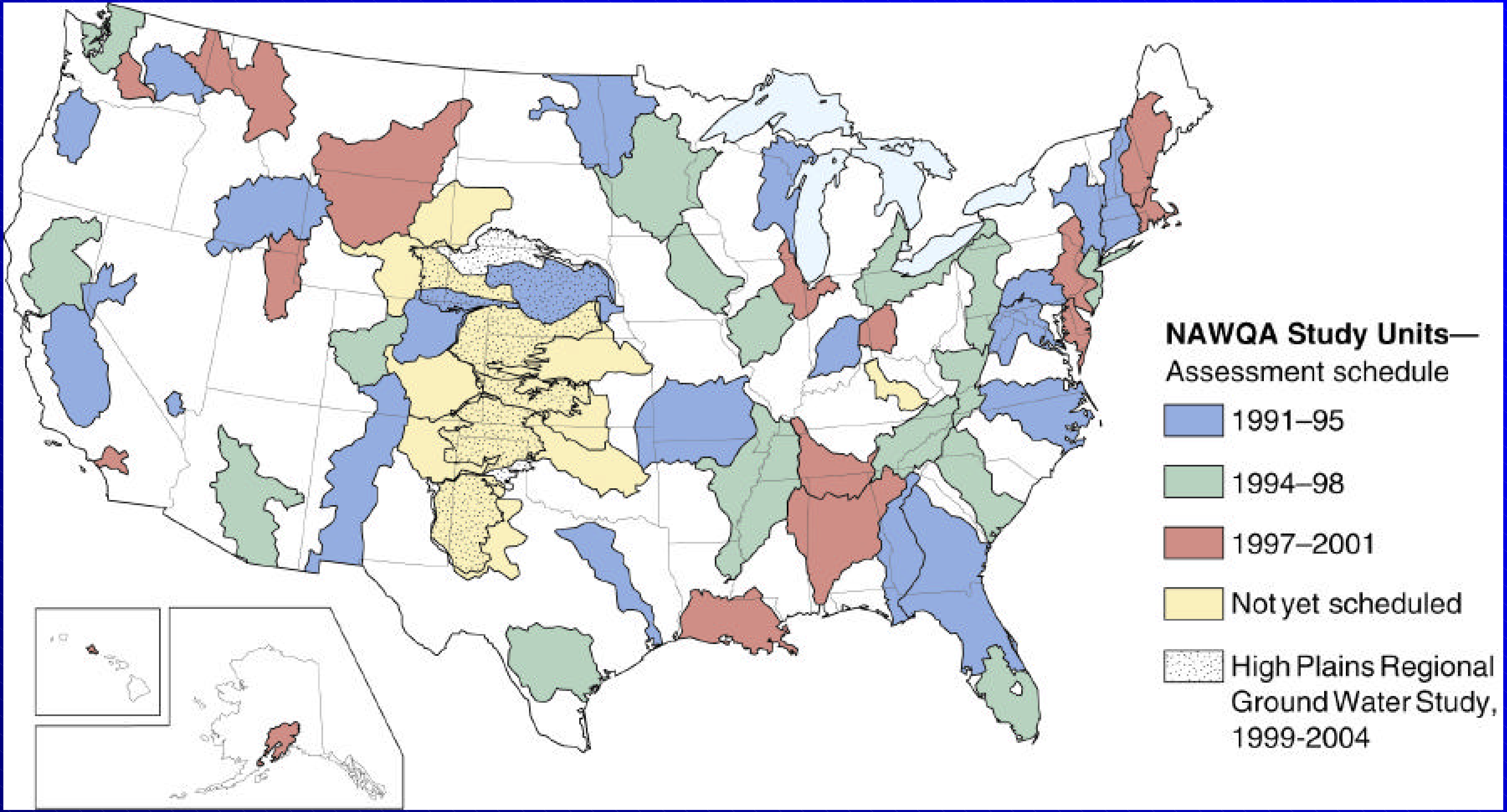
- **Algal collection methods**
  - Different substrates
  - Quantifying taxonomic variation by substrate type
- **Laboratory methods**
  - Biomass
    - Different Chlorophyll methods
    - Quality Assurance
- **Nutrients and algal community response**
  - Yellowstone (headwater to large river)
  - Ohio (small and large streams, benthic & planktonic)
  - New England coastal (reference-impaired, riparian)

USGS

SUMMARY OF ALGAL METHODS USED THROUGHOUT REGION 5

STATE & WATERBODY	PLANKTON	BENTHIC	COLLECTION METHOD	CHLOROPHYLL A METHOD
ILLINOIS				
Stream/River	X		integrated water sample	SPEC
Lake/Reservoir	X		integrated water sample at 2x SD	SPEC
INDIANA				
Stream/River	X	X	water samples; rock scrapes	FLUOR
Lake/Reservoir				
MICHIGAN				
Stream/River				
Lake/Reservoir	X		water sample at 2.5X secchi depth	SPEC
MINNESOTA				
Stream/River		X	rock and woody debris scrapes	FLUOR?
Lake/Reservoir	X		integrated water sample	
OHIO				
Stream/River	X	X	water samples; rock scrapes	FLUOR
Lake/Reservoir				
WISCONSIN				
Stream (wadeable)	X	X	water samples; rock scrapes;	SPEC
River (non-wadeable)	X		water samples	SPEC
Lake/Reservoir	X		water samples	SPEC

National Water Quality Assessment Program



http://water.usgs.gov\nawqa\

Collecting rocks from stream into dishpan for processing on the stream bank.

Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment Program

Moulton, Stephen R., II; Kennen, Jonathan G.; Goldstein, Robert M.; Hambrook, Julie A.

OFR 2002-150 http://water.usgs.gov\nawqa\

SG-92 with o-ring, brush, and rock to be scraped in dishpan.

Top rock scrape method: scraped area of a cobble covered with foil to determine the area sampled.

Cylinder scrape method for woody snags

Inverted Petri dish used to collect a depositional sample by inserting a spatula to remove from the stream bottom.

USGS

Gavel sampler: beveled edge on bottom improves coring into gravel substrate.

PVC pipe from a plumbing clean-out trap.

USGS

Artificial substrates used in the Santa Ana Basin to collect periphyton.

USGS

Filtering apparatus; hand operated pump, Erlenmeyer flask, tubing, filter funnel and base.

- Record the area scrapped
- Record the volume before preservative
- Record the volume of the subsample taken:
  - chlorophyll,
  - ash-free dry mass, or
  - taxonomic identification and enumeration

USGS

Battery operated sample homogenizer

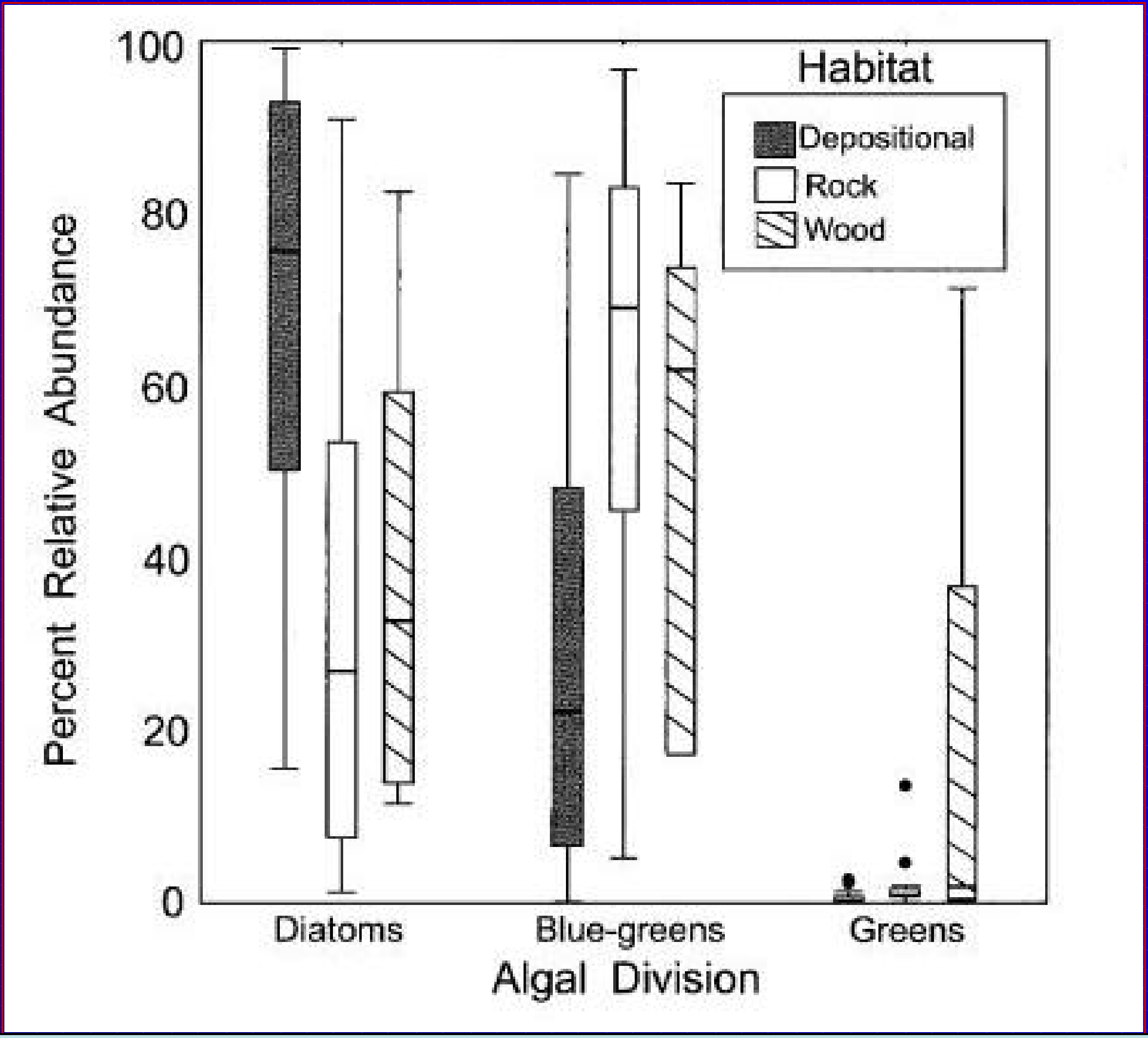
USGS

Pipette measured amounts from the homogenized sample onto the filter in the filter funnel.

Wrap aluminum foil around folded filter before placing in sample container.

Place label on container (Petri dish) and keep frozen in a plastic bag.

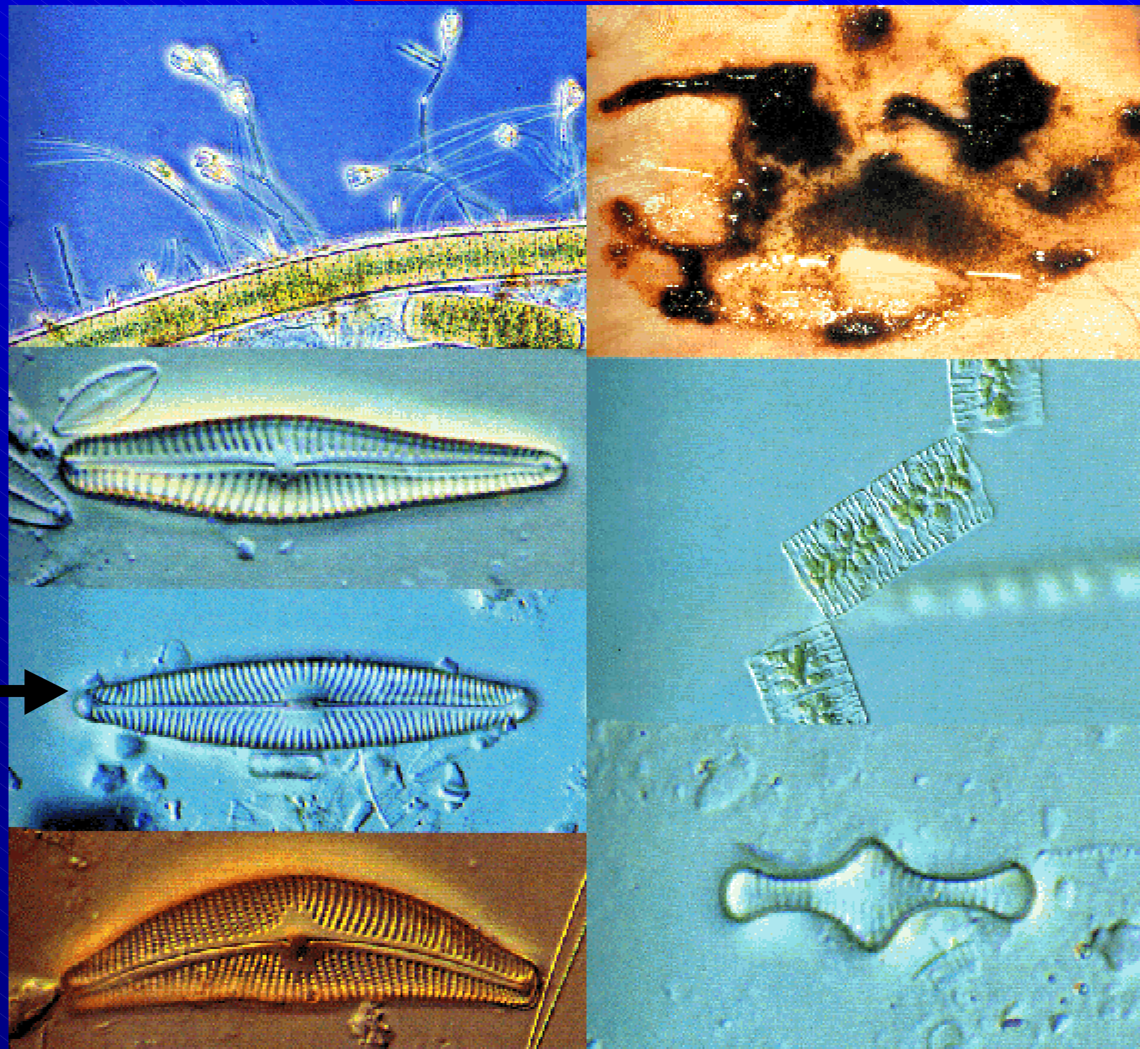
Does the sample substrate make a difference in the results?



Carpenter and Waite, 2000, Environmental Monitoring and Assessment

DIATOMS

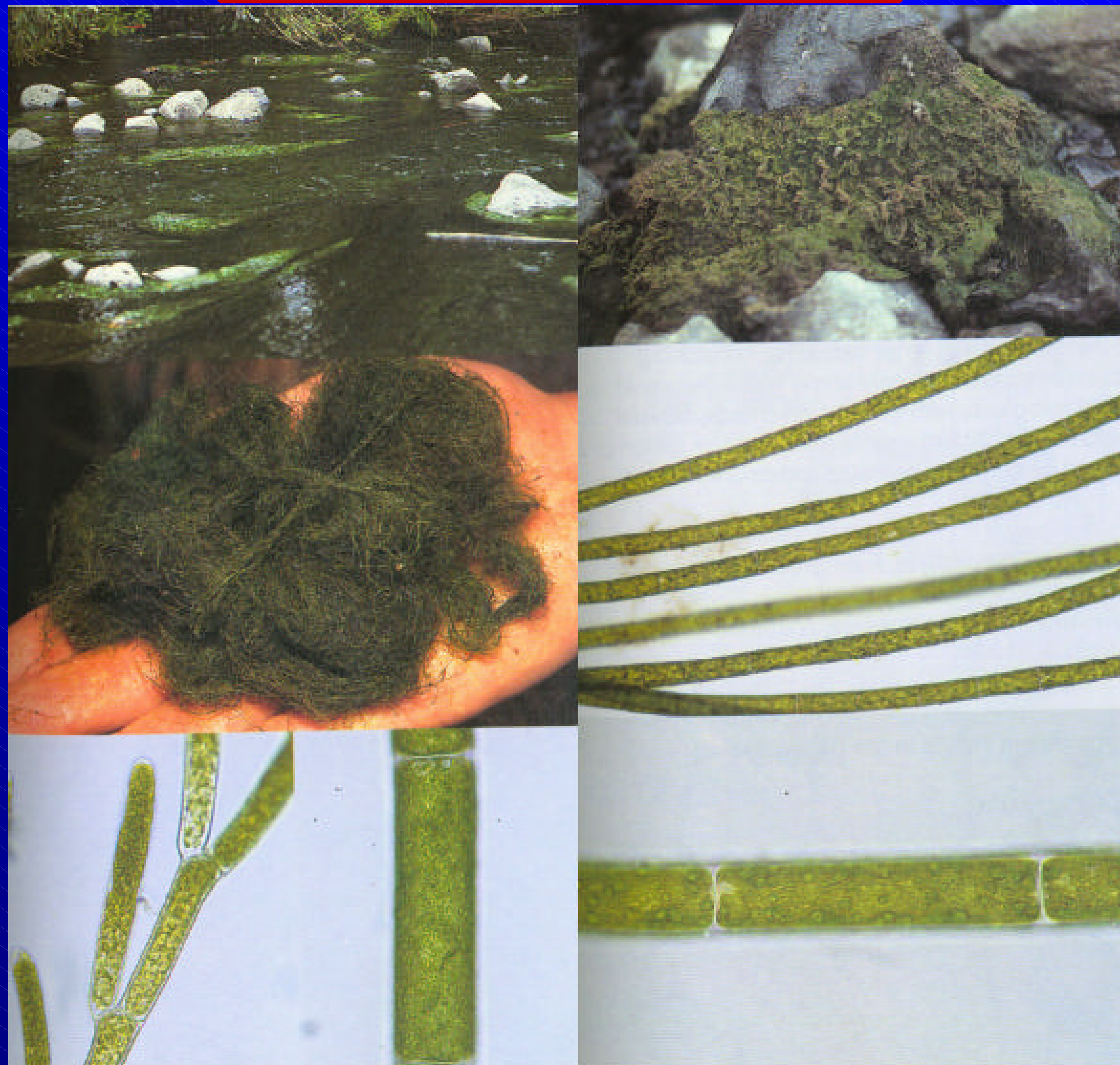
NAVICULA



GOMPHONEMA TABELLARIA

Entwistle and others, 1997

GREEN ALGAE

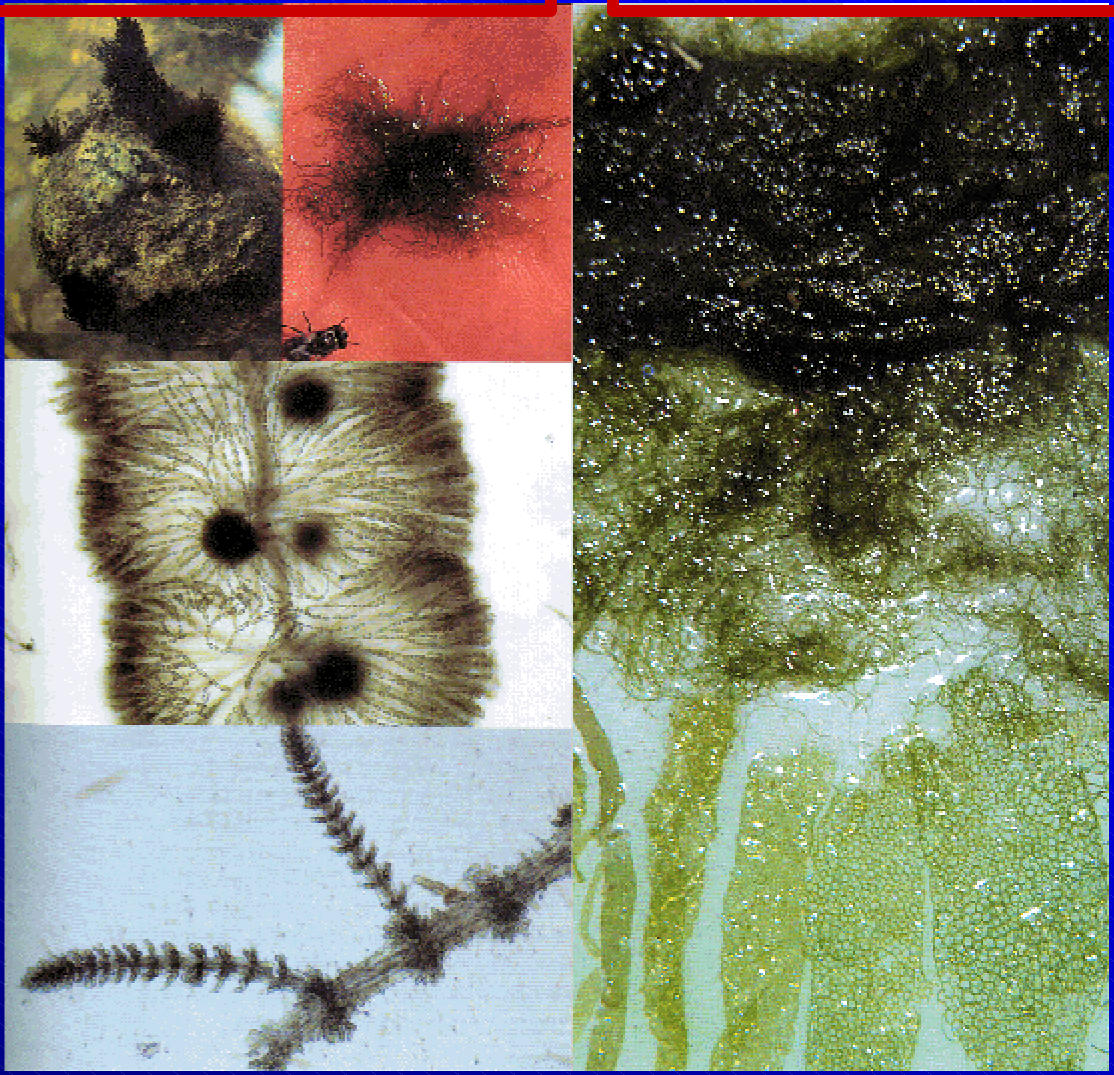


CLADOPHORA RHIZOCLONIUM

Entwistle and others, 1997

RED ALGAE

GREEN ALGAE



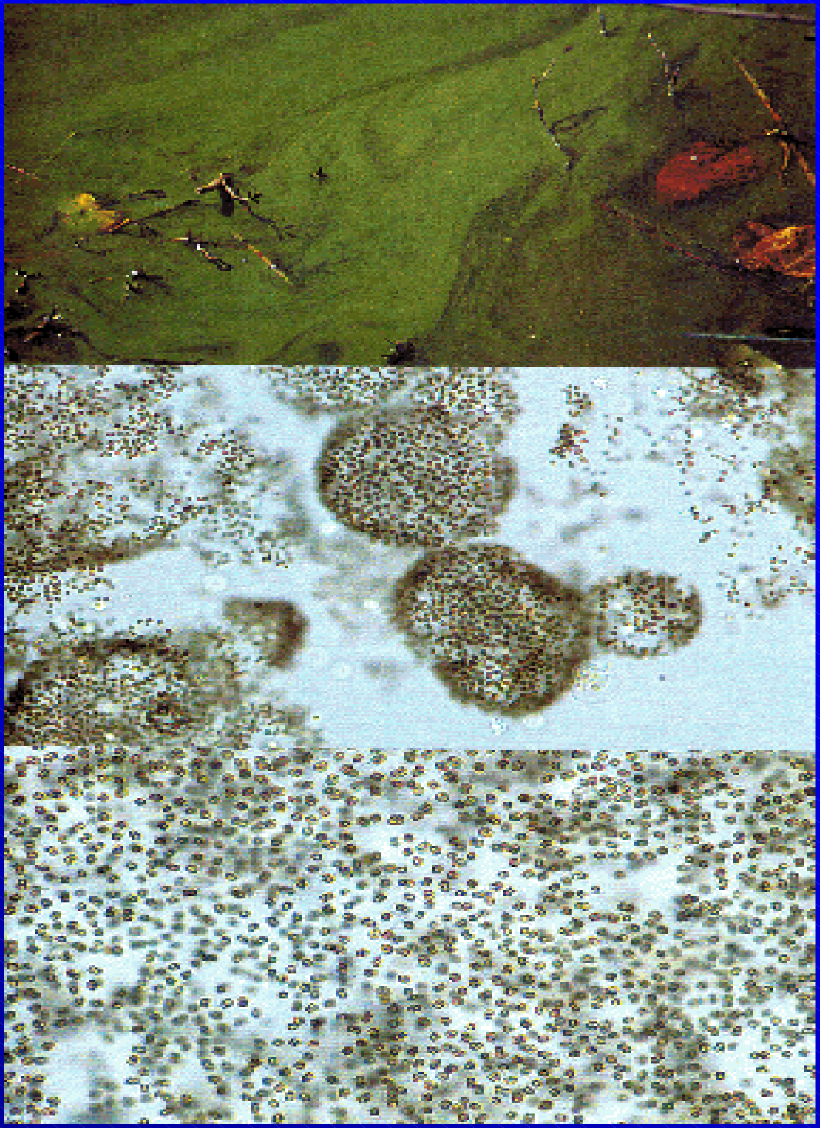
BATRACHOSPERMUM HYDRODICTYON

Entwistle and others, 1997

Ditch with thick growth of the green alga, *Hydrodictyon* dominant

BLUE-GREEN ALGAE

Cyanobacteria



MICROCYSTIS

Entwistle and others, 1997

What does the comparison of National datasets from depositional and erosional substrates show?

Data used from: 48 Study Units, ~ 1100 sampling sites

RTH - erosional
Rocks and snags (woody debris)

DTH - depositional
Soft sediment

Depositional (DTH) and Erosional (RTH) samples are more different at the National scale but not always significantly different at the local scale.

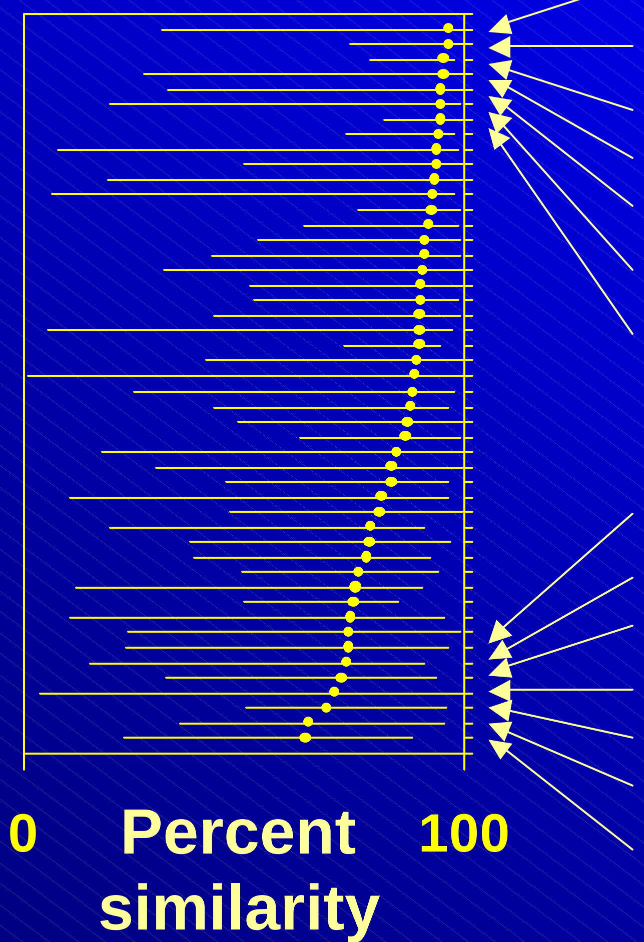
• CCA was used with 'DTH-RTH' as the only constraining variable; permutation tests used to check for significance of the effect

• Two datasets containing one pair of DTH and RTH samples per site, taken at the same time and at the same reach:

1) diatoms only, 1280 samples from 640 sites, 48 Study Units
2) all algae, 904 samples from 452 sites, 36 Study Units

Geomorphology influences similarity of diatom assemblages in DTH and RTH samples

48 Study Units ranked by median value of Percent Similarity (DTH vs. RTH)



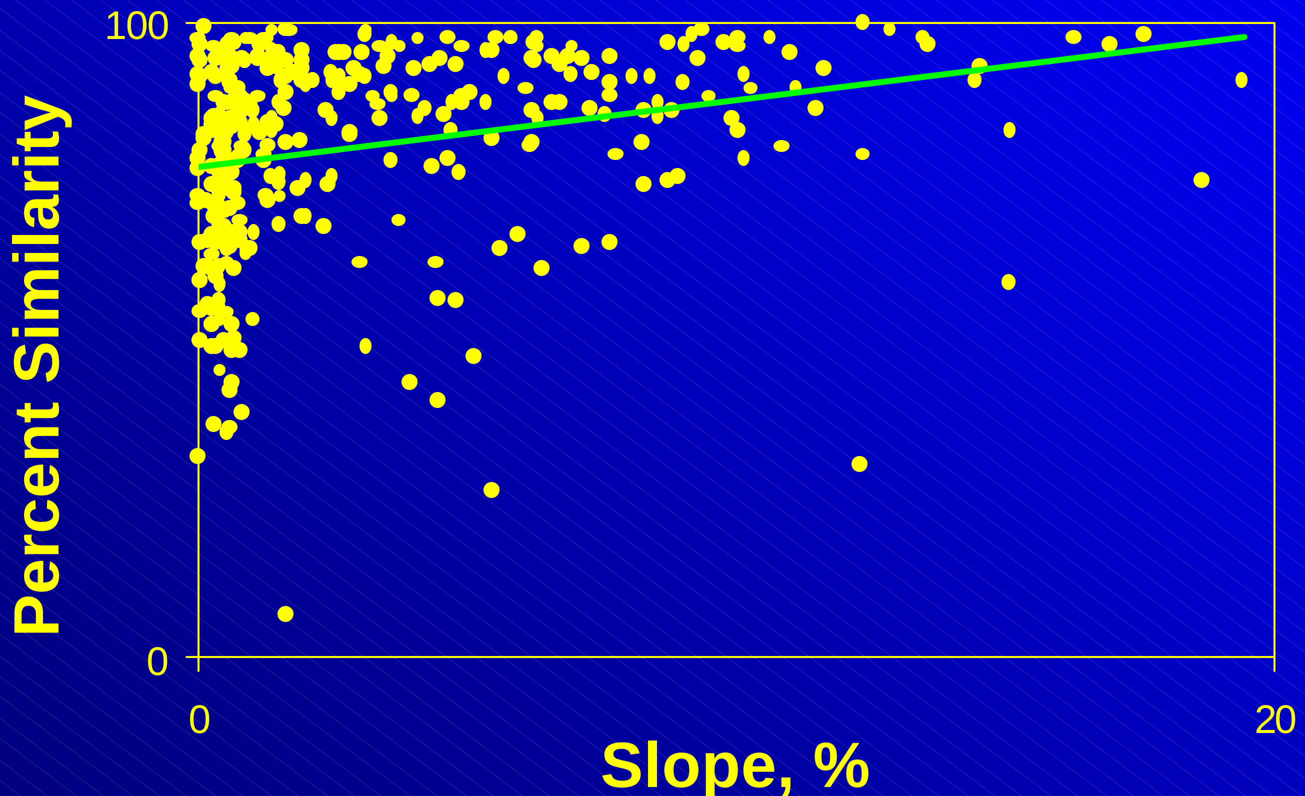
Upper Colorado River Basin
Ozark Plateaus
Upper Snake River Basin
New England Coastal Basins
Potomac River Basin
Cook Inlet Basin
Allegheny & Monongahela Basins

Lake Erie -Lake St.Clair Drainage
Southern Florida
White River Basin
Red River of the North Basin
Lower Illinois River Basin
Eastern Iowa Basin
Mississippi Embayment

USGS

Marina Potapova, 2002 The Academy of Natural Sciences

Percent Similarity (diatoms) vs. Mean Watershed Slope



Spearman correlation coefficient = 0.42,

significance < 0.001,

n = 359

Marina Potapova, 2002 The Academy of Natural Sciences

Values of simple diatom metrics differ significantly ($p<0.05$) between DTH and RTH samples (results of Kruskall-Wallis ANOVA)

DTH>RTH

- Number of taxa (diatoms and total)
- Shannon diversity (diatoms and total)
- Centrales/Pennales
- Siltation index
- % Achnanthes minutissima
- Total algal biovolume
- Biovolume of diatoms
- Biovolume of euglenoids
- Biovolume of Xanthophyta (golden algae)

RTH>DTH

- Number of non-diatom taxa
- % of 10 dominant diatom taxa
- % of dominant diatom taxon
- Biovolume of cyanobacteria
- Biovolume of red algae
- Biovolume of green algae

USGS

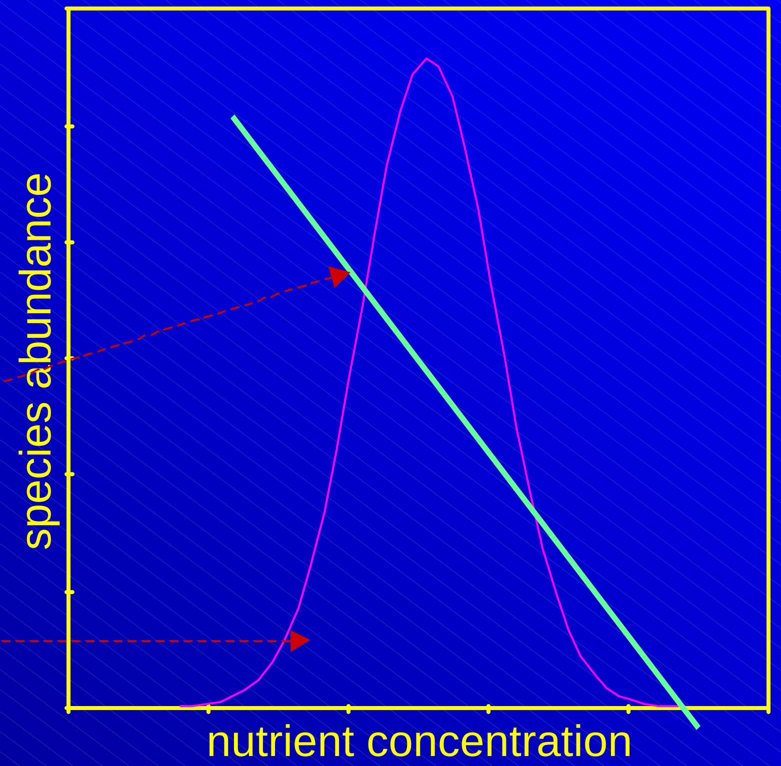
Comparison of metrics calculated for RTH samples taken from rocks and snags (results of Mann-Whitney test, $p<0.05$)

Number of taxa (diatoms and total)	rocks < snags
Shannon diversity (diatoms and total)	rocks < snags
% of dominant diatom taxon	rocks > snags
Centrales/Pennales	rocks < snags
Siltation index	rocks < snags
% Achnanthes minutissima	rocks > snags
Total algal biovolume	rocks > snags
Biovolume of cyanobacteria	rocks > snags
Biovolume of red algae	rocks > snags
Biovolume of euglenoids	rocks < snags
Biovolume of Xanthophyta	rocks < snags

Species responses to nutrients examined by traditional approaches

- Expert opinions
- Weighted averaging
- Fitting parametric regression:

  linear
  or non-linear



Indicators of low TP (apparent optima < 50 μg/L)

hard substrate

Geissleria decussis

Meridion circulare

Achnanthidium affinis

hard substrate and soft sediment

Achanthes cf. *linearis*

Encyonema minutum

Navicula cryptocephala

Achnanthes subhudsonis

Achnanthidium minutissimum

soft sediment

Surirella angustata

Fragilaria capucina

Indicators of high TP (apparent optima > 150 μg/L)

hard substrate

Melosira varians
Diadesmis contenta
D. confervacea
Meridion circulare
Cyclotella meneghiniana

hard substrate and soft sediment

Nitzschia palea
N. fonticola
Gomphonema olivaceum
Navicula subminuscula

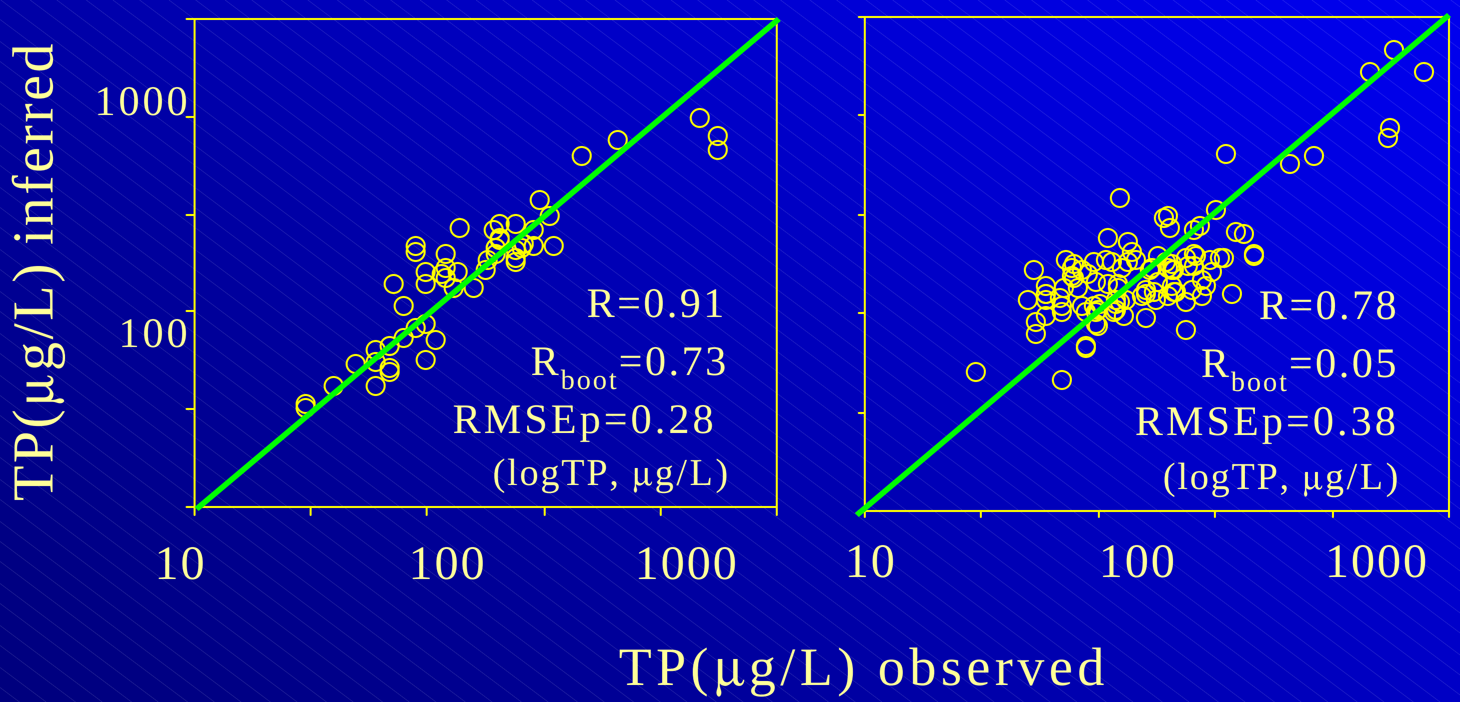
soft sediment

Diatoma vulgaris
Sellaphora pupula
Cocconeis pediculus
Amphora copulata
Luticola goeppertiana

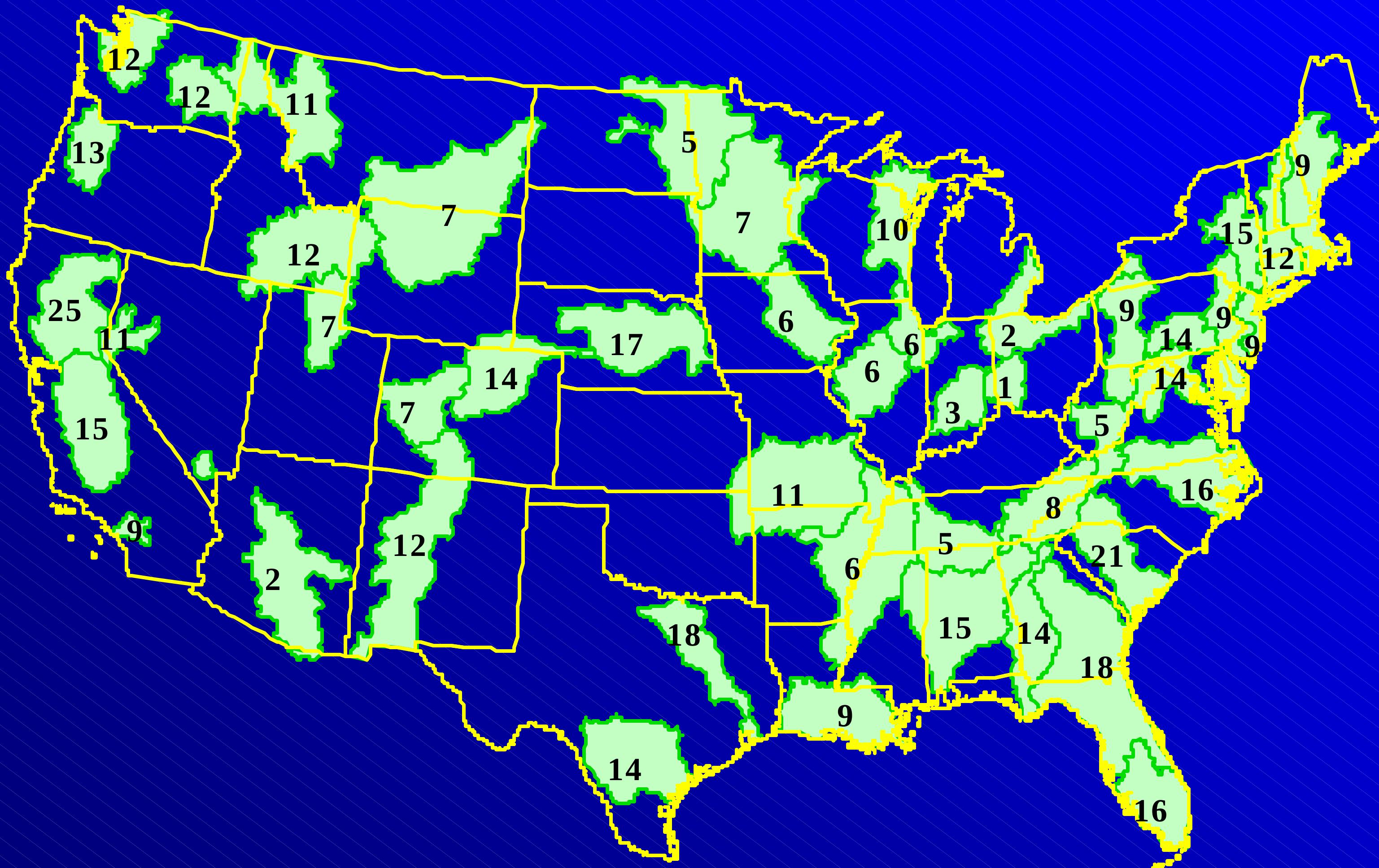
Diatom-based TP inference models for the Central Plains Ecoregion

Model based on 55 samples from soft sediment

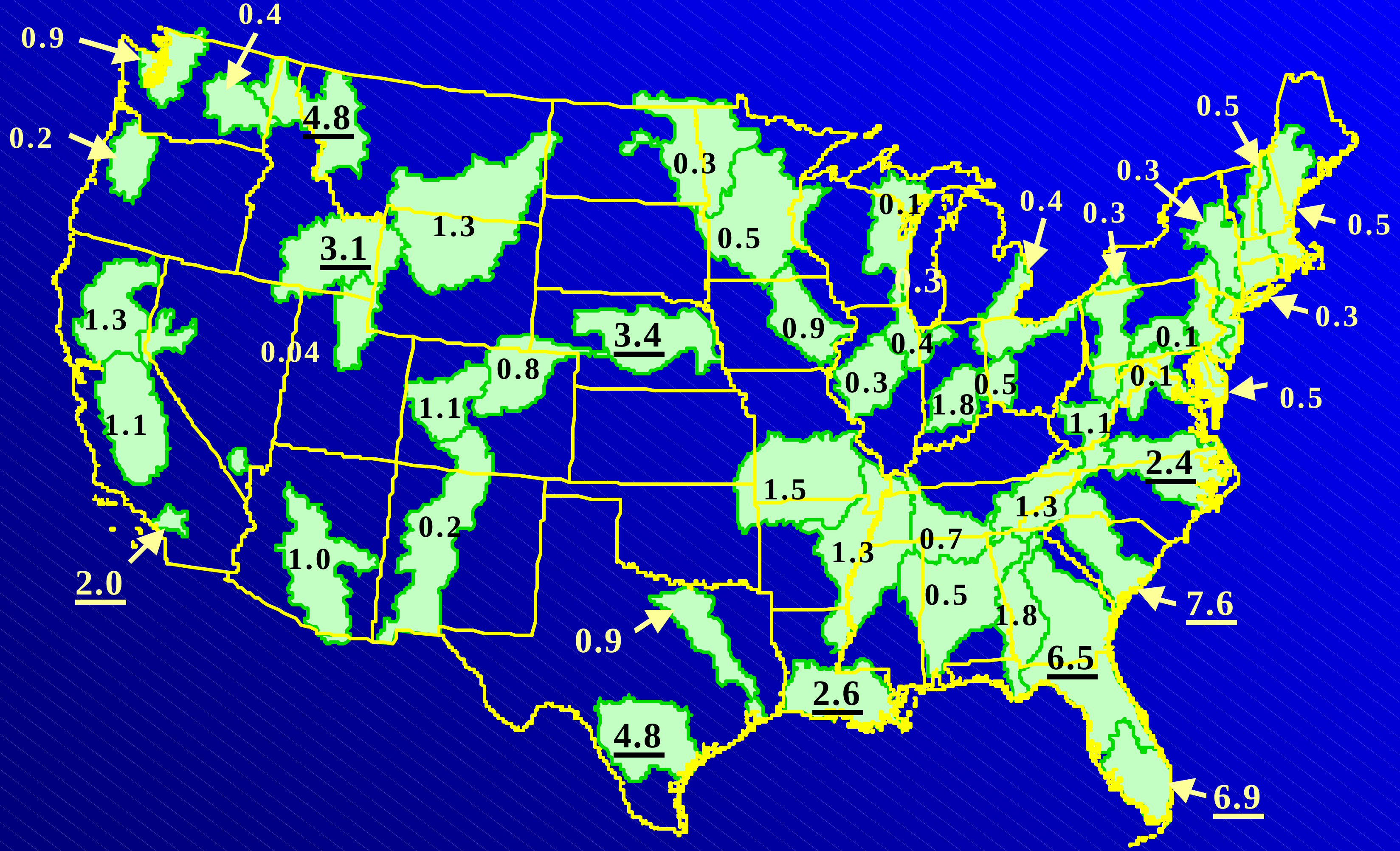
Model based on 108 samples from snags



Total number of ‘native’ species



Average relative abundance of rare species per sample



Diatom taxa can serve as additional evidence

- Indicator taxa have been identified, inference models can be tested for areas of interest
- Number and relative abundance of rare and 'native' diatom species tend to be higher in less disturbed rivers, but also at low altitudes and latitudes
- Presence or abundance of rare and native species cannot be used alone to estimate water quality, but can serve as additional evidence of ecosystem condition

See New Jersey approach

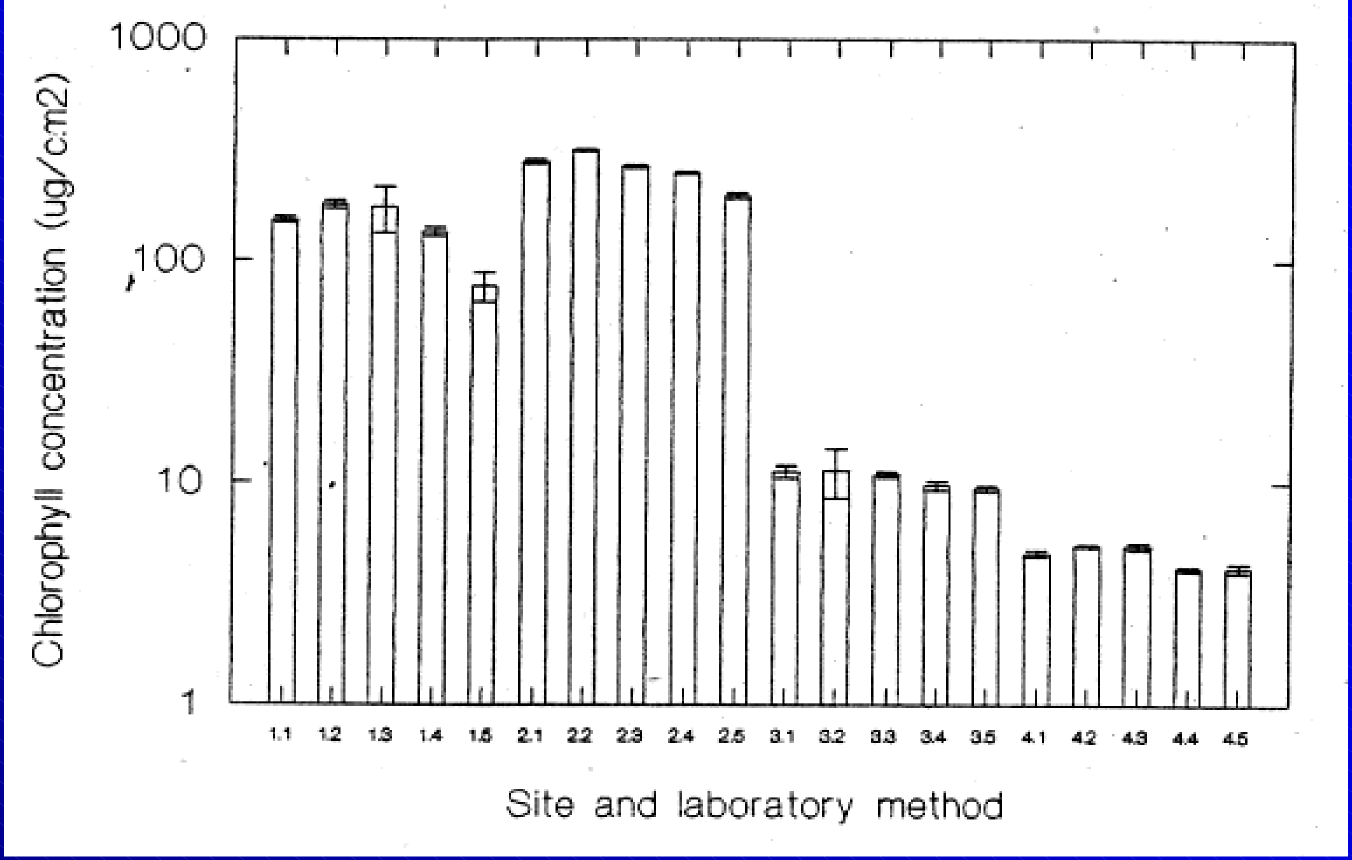
http://www.state.nj.us/dep/dsr/wq/wq.htm

USGS

Chlorophyll Sample Analysis

- Different types of analysis
  - Spectorphotometric
  - Fluorimetric
  - HPLC
- Variance within laboratory
- Variance between laboratories
- Data quality and measurement quality objectives

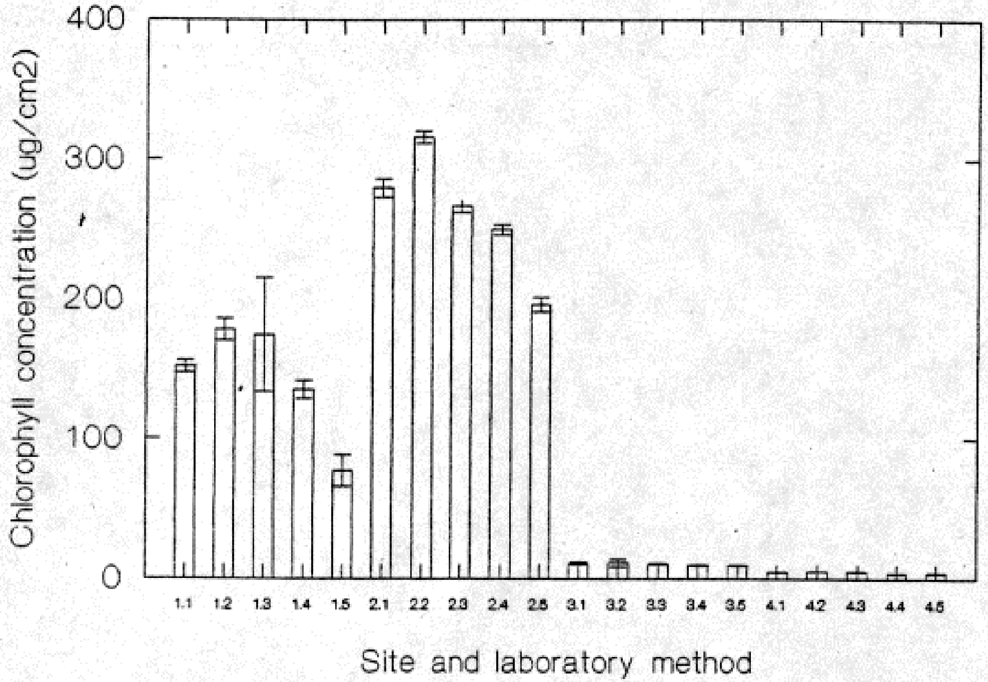
Chlorophyll concentrations from 4 sites with 5 methods



- X.1 = Spectrophotometric #1 (“corrected”)
- X.2 = Spectrophotometric #2 (“uncorrected”)
- X.3 = Fluorometric
- X.4 = HPLC (EPA)
- X.5 = HPLC (NWQL)

USGS

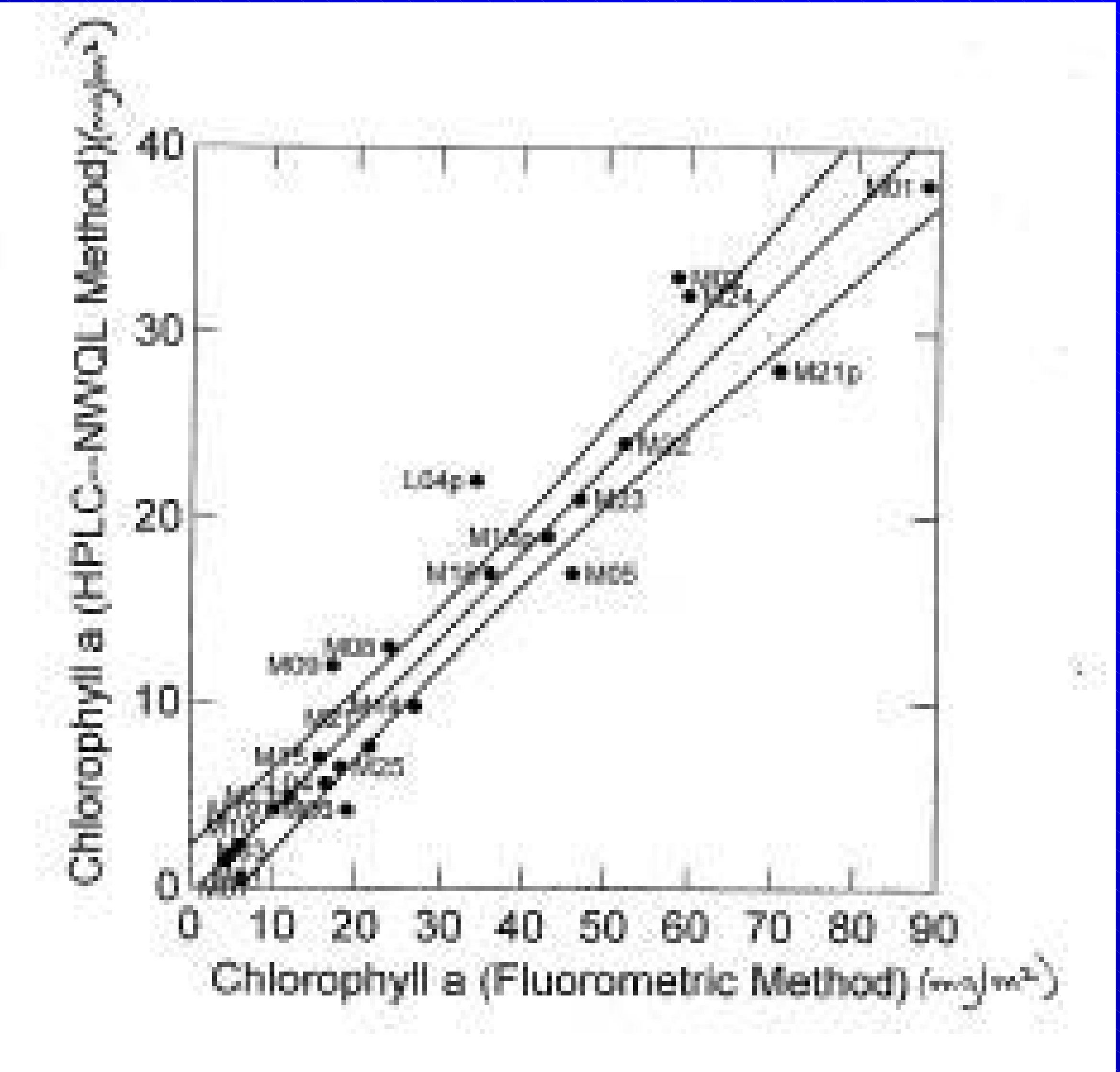
Chlorophyll concentrations in ug/cm2 from 4 sites analyzed using 5 methods



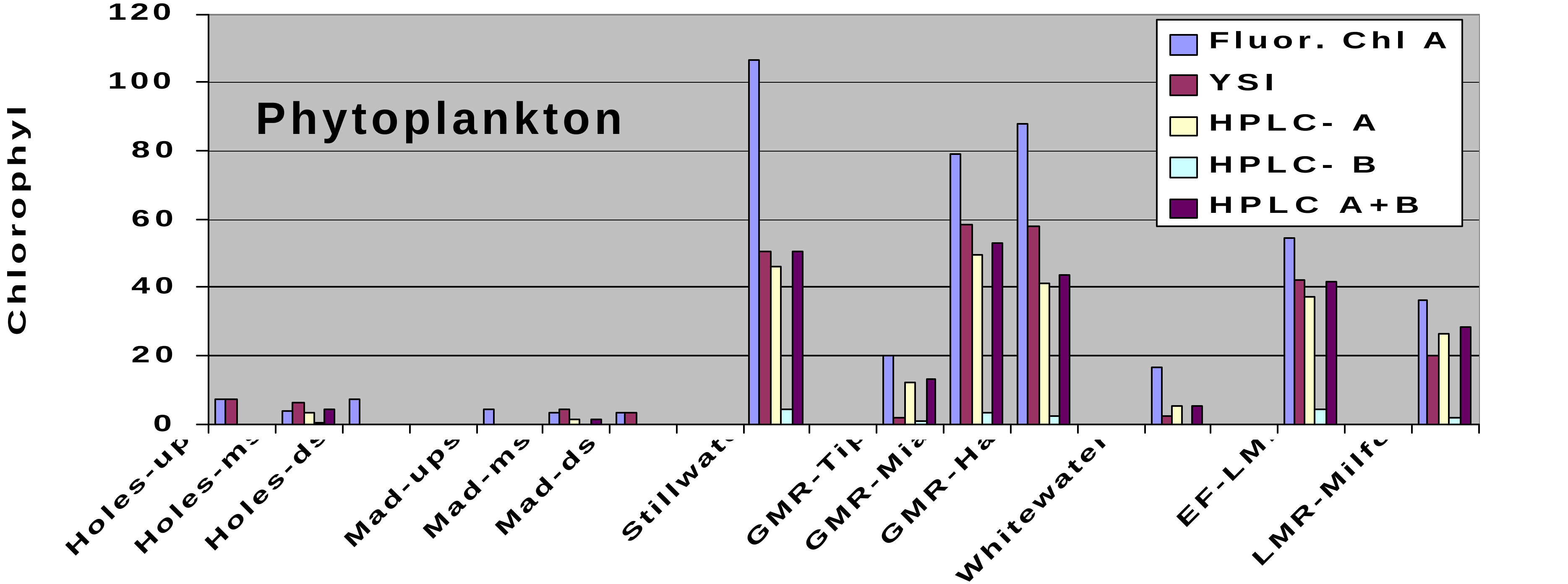
X = Sites

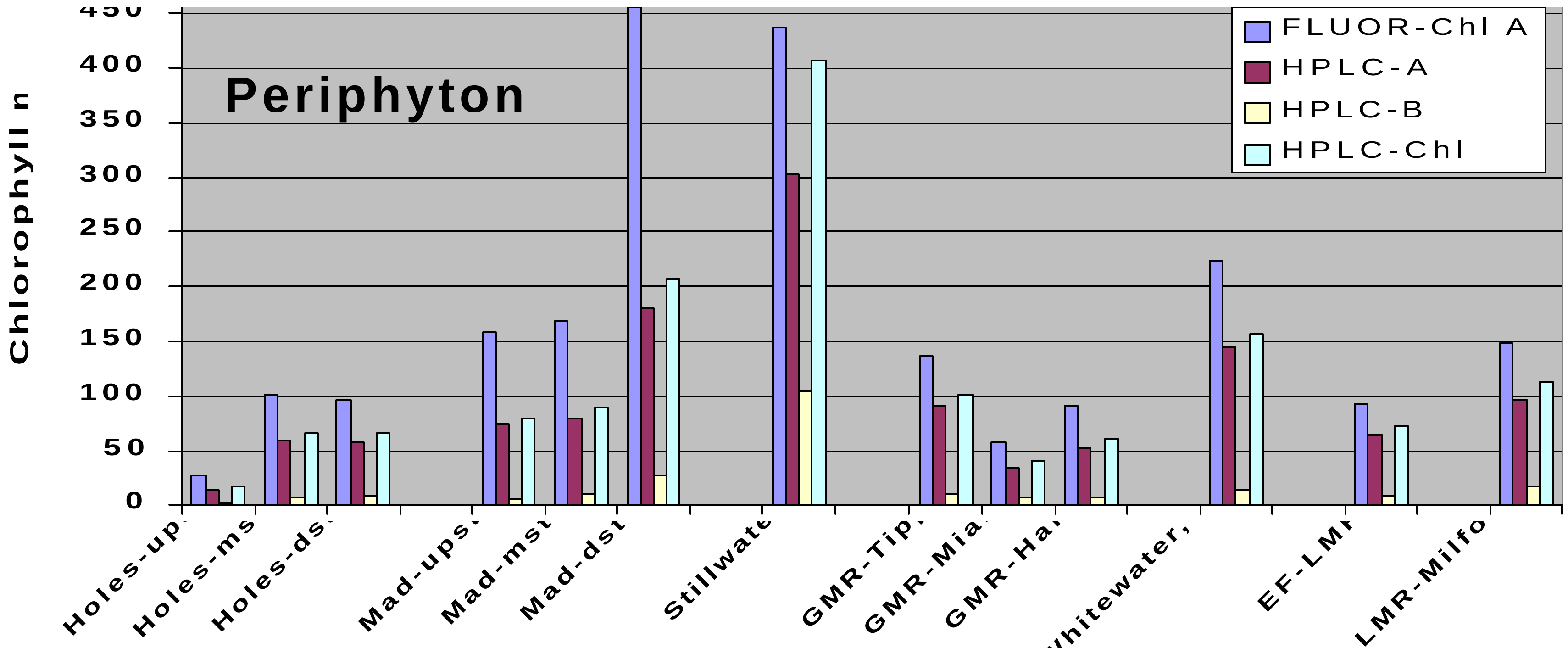
X.1 = Spectrophotometric method #1 ("corrected")
X.2 = Spectrophotometric method #2 ("uncorrected")
X.3 = Fluorometric method
X.4 = HPLC method #1 (EPA)
X.5 = HPLC method #2 (NWQL)

Comparison between HPLC and Fluorometric methods analyzing Chlorophyll a

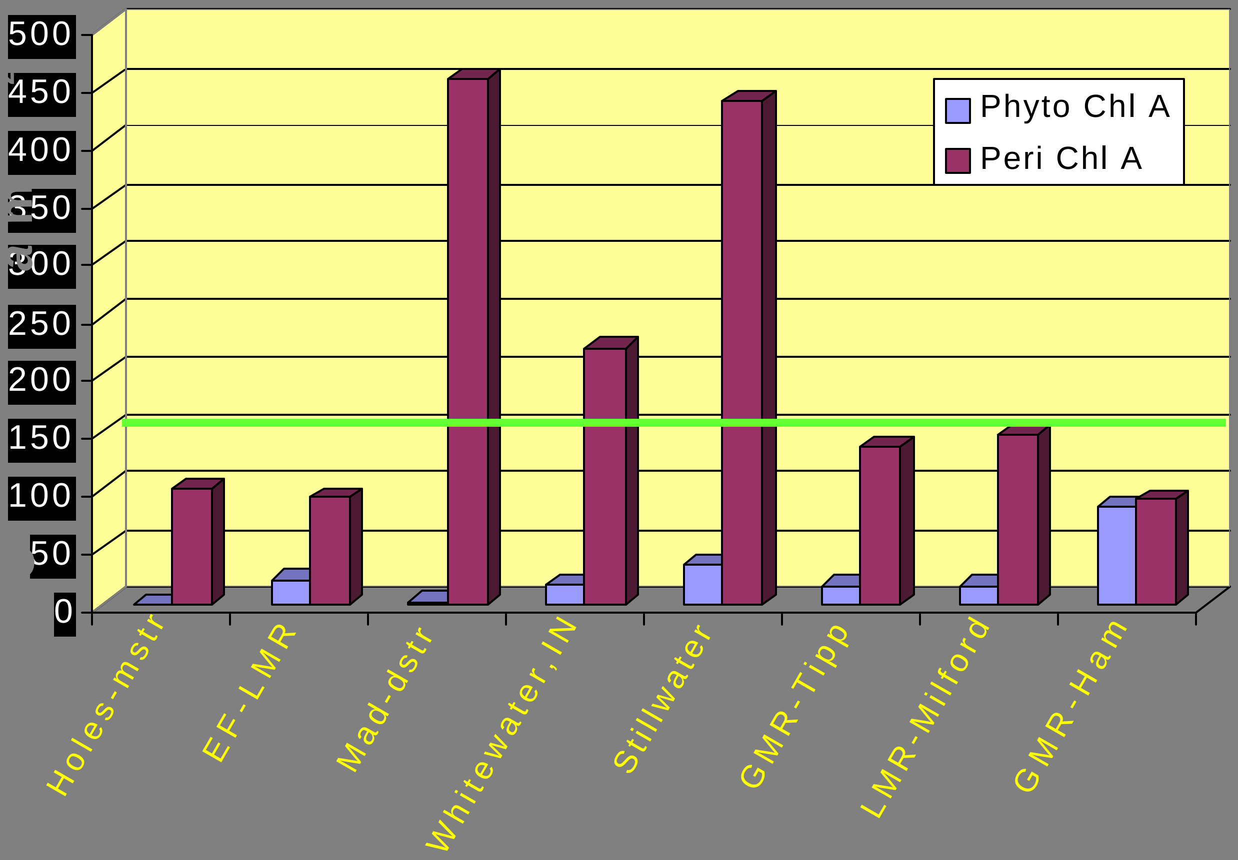


Fluorometric chlorophyll analysis method lab comparisons


Phytoplankton
Chlorophyl
0
20
40
60
80
100
120
Fluor. Chl A
YSI
HPLC- A
HPLC- B
HPLC A+B
Holes-up
Holes-ms
Holes-ds
Mad-ups
Mad-ms
Mad-ds
Stillwate
GMR-Tip
GMR-Mia
GMR-Ha
Whitewater
EF-LM
LMR-Milfo

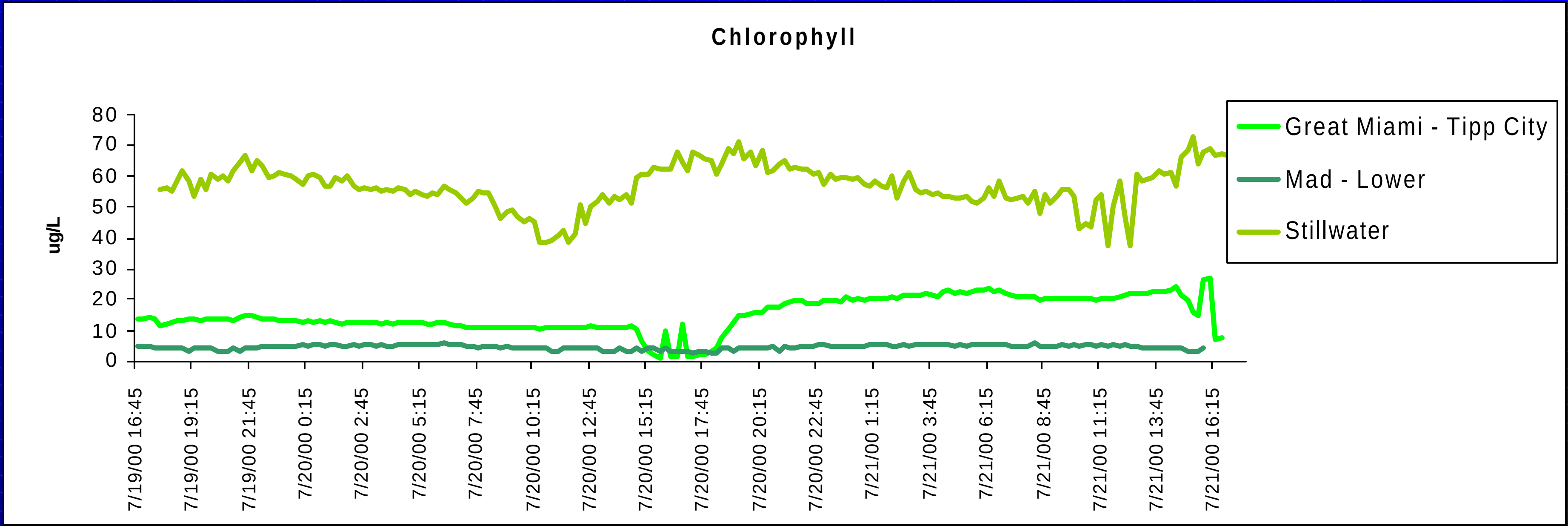

Periphyton
Chlorophyll n
0
50
100
150
200
250
300
350
400
450
FLUOR-Chl A
HPLC-A
HPLC-B
HPLC-Chl
Holes-up
Holes-ms
Holes-ds
Mad-ups
Mad-ms
Mad-ds
Stillwate
GMR-Tip
GMR-Mia
GMR-Ha
Whitewater,
EF-LM
LMR-Milfo

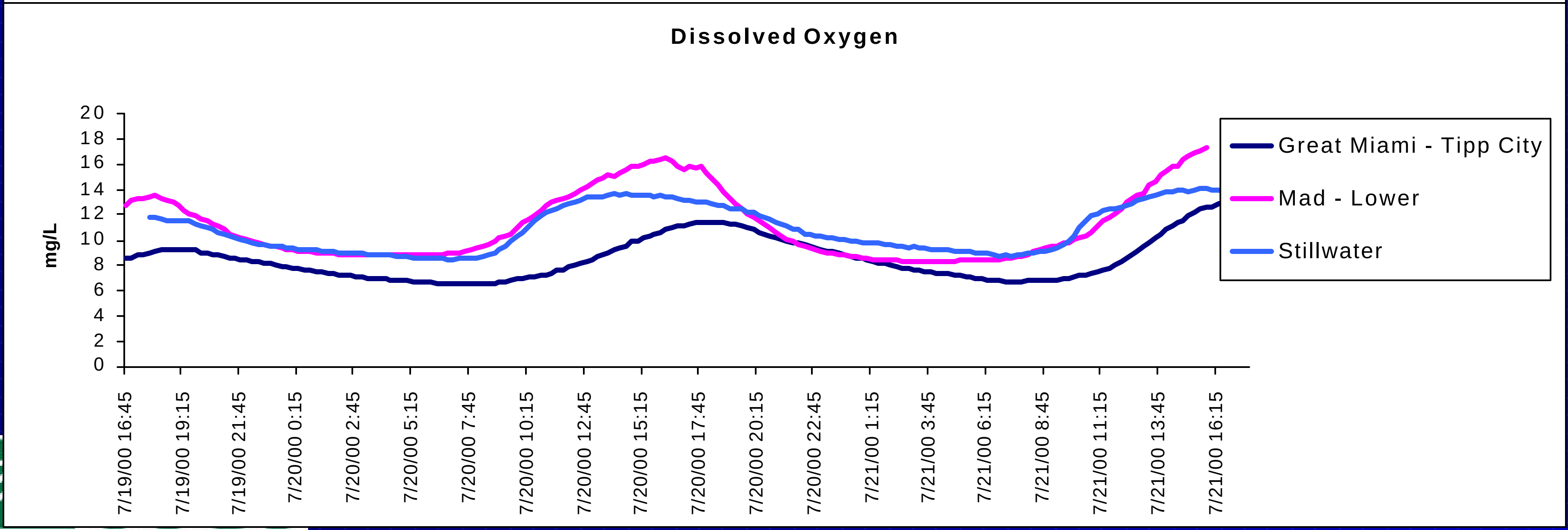
Phytoplankton and Periphyton Chlorophyll *a* mg/m3 July 2000

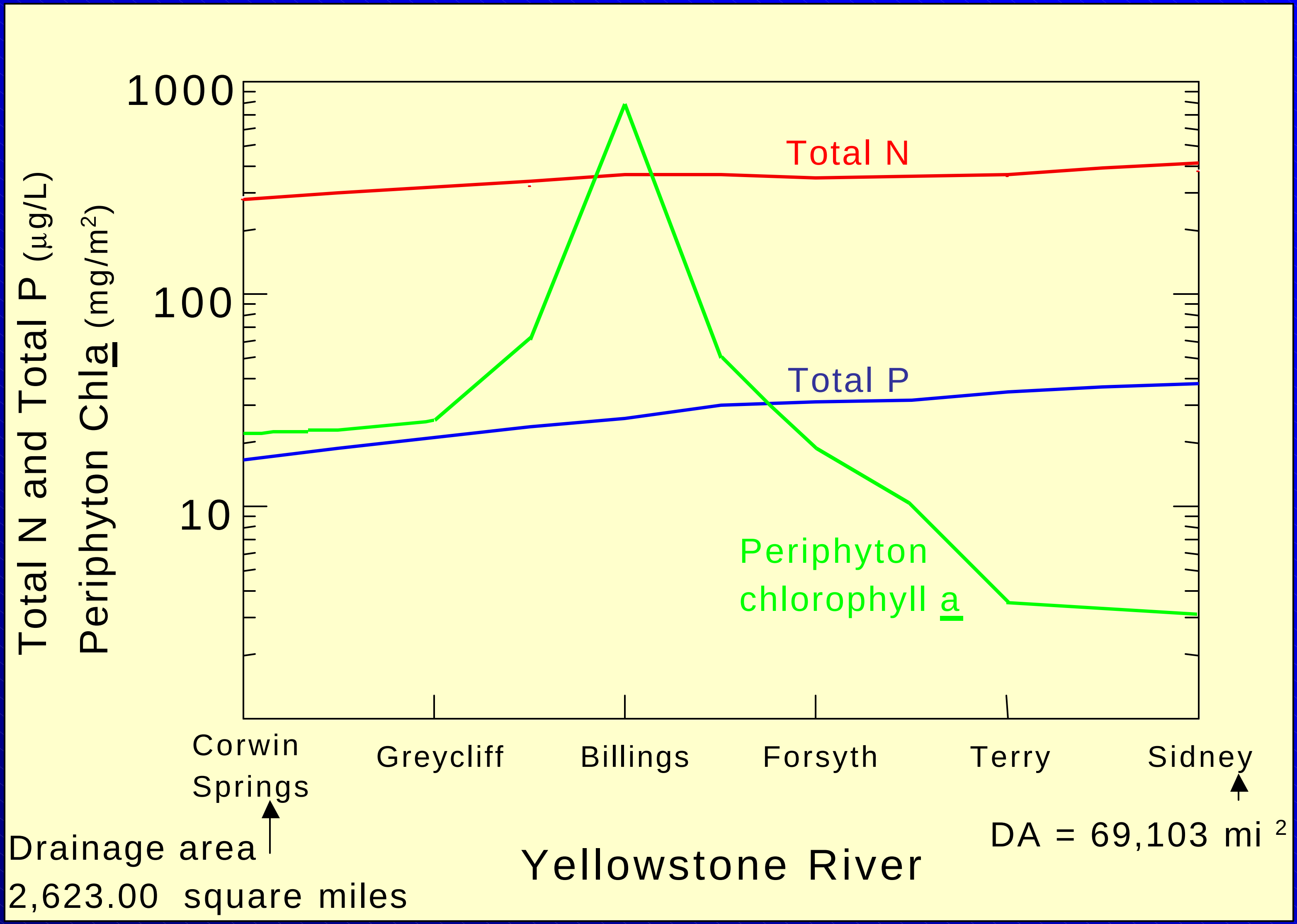


Drainage area 20 square miles → 3,636 square miles

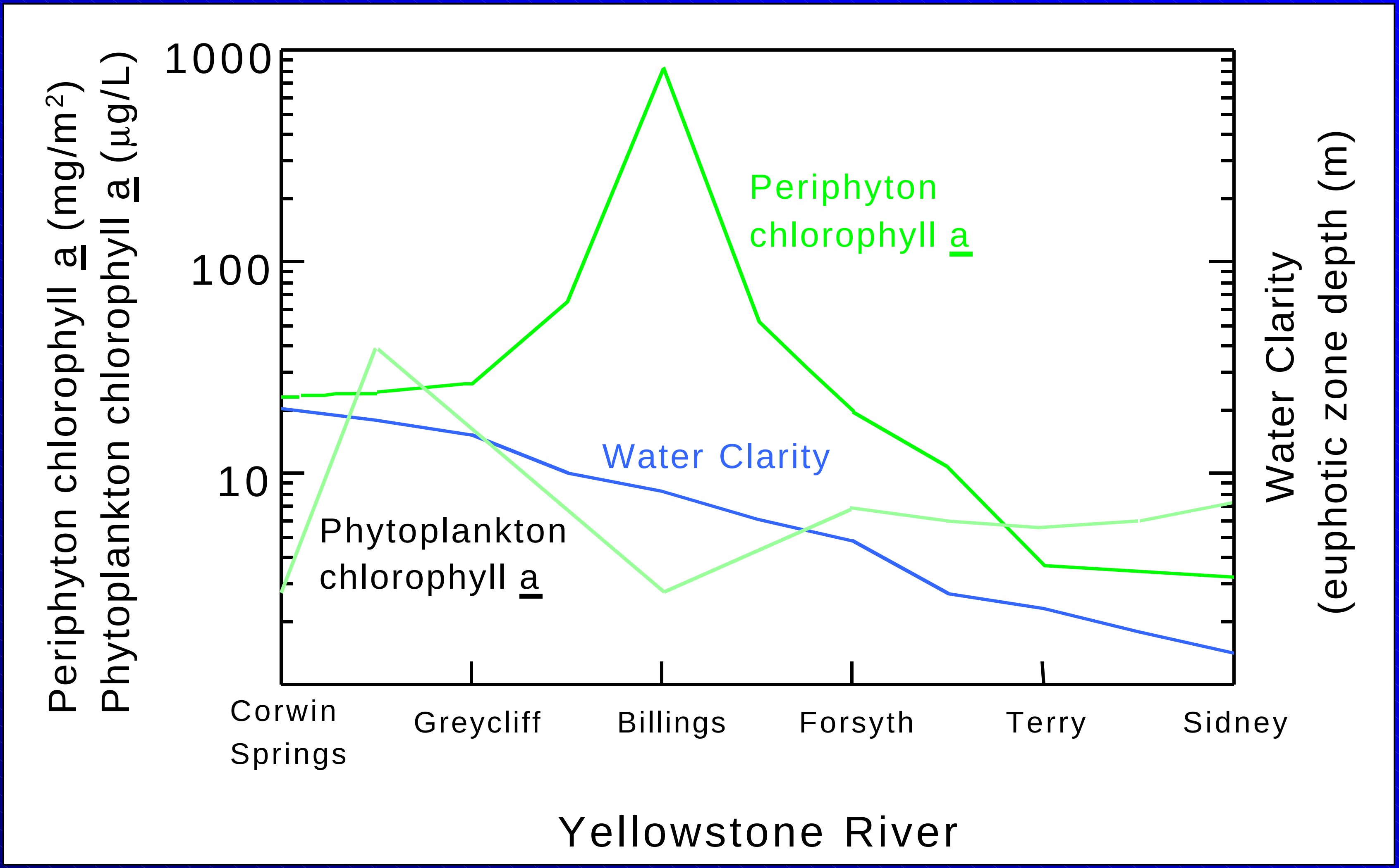
Upper Tributaries – Great Miami, Mad, and Stillwater





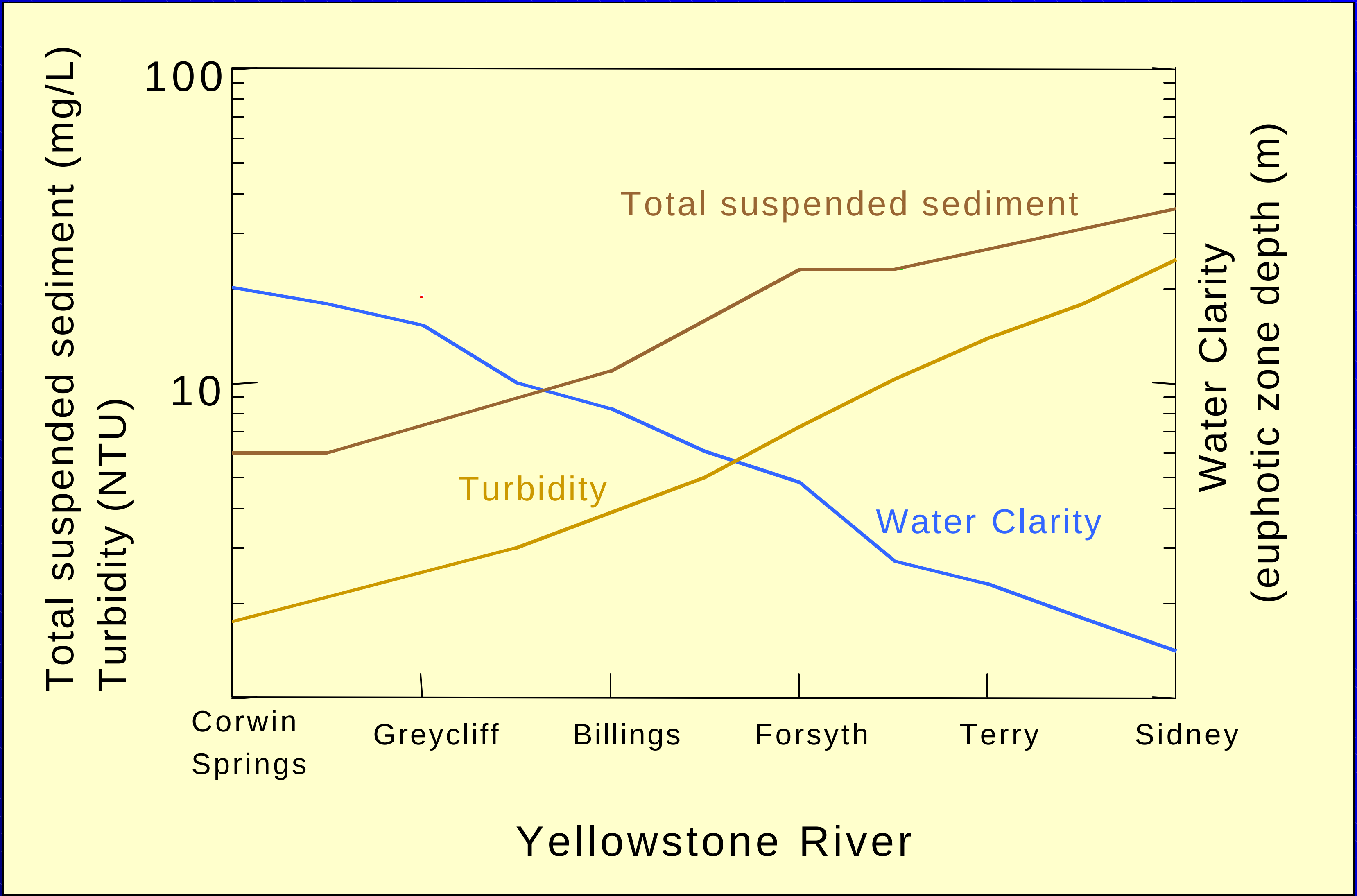


With permission from S.D. Porter who worked with David A. Peterson

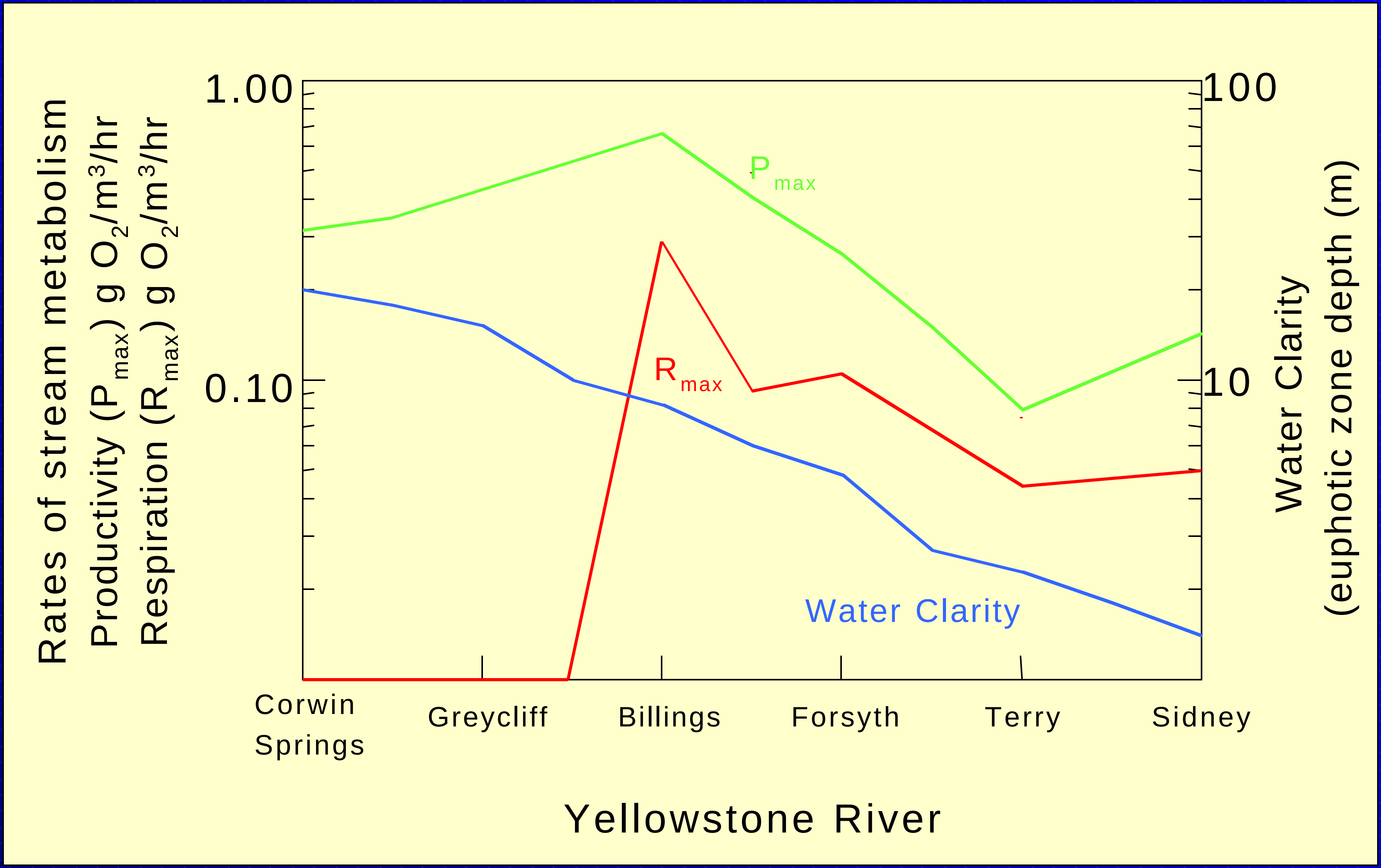


With permission from S.D. Porter who worked with David A. Peterson

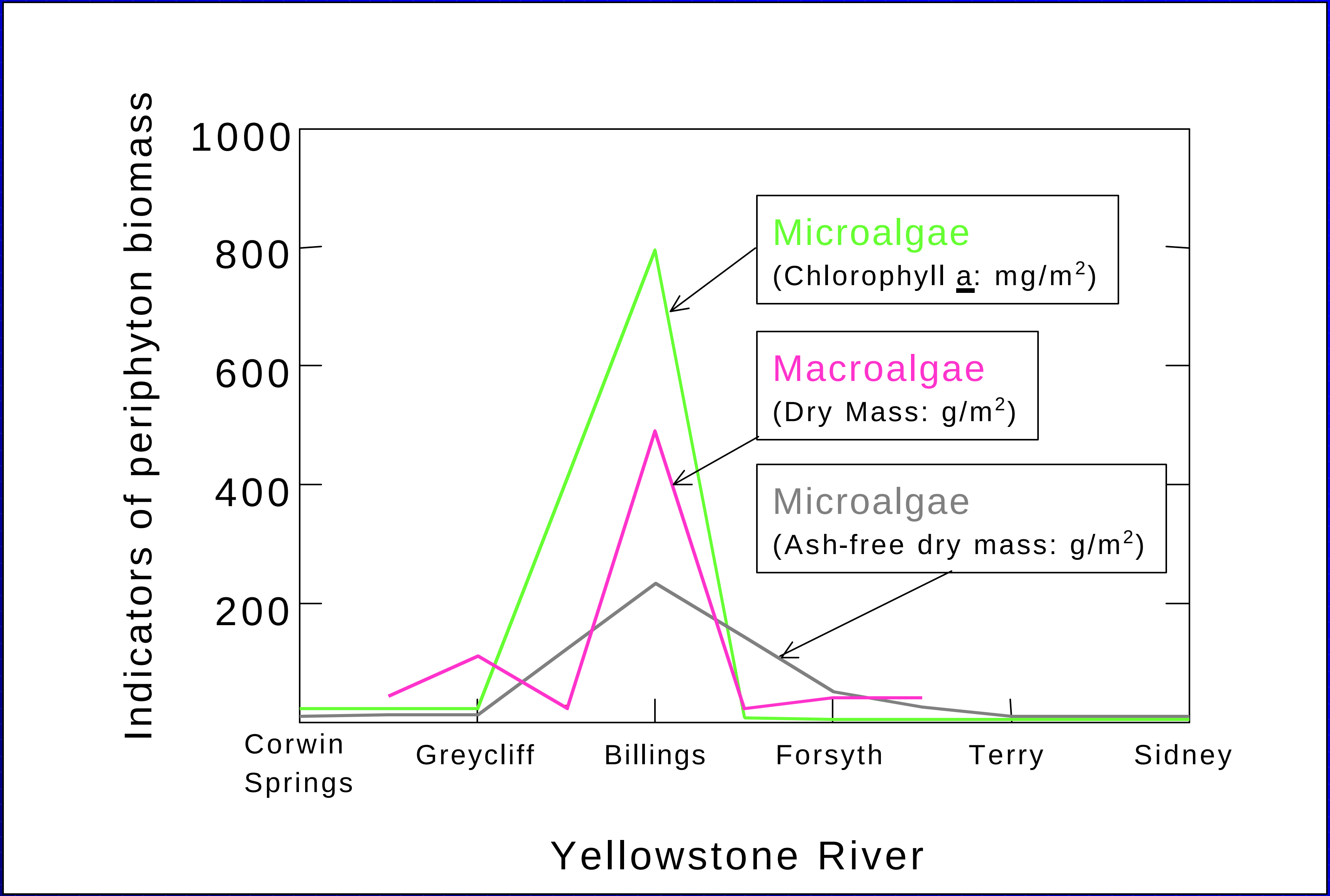
Measuring light availability with depth



With permission from S.D. Porter who worked with David A. Peterson



With permission from S.D. Porter who worked with David A. Peterson

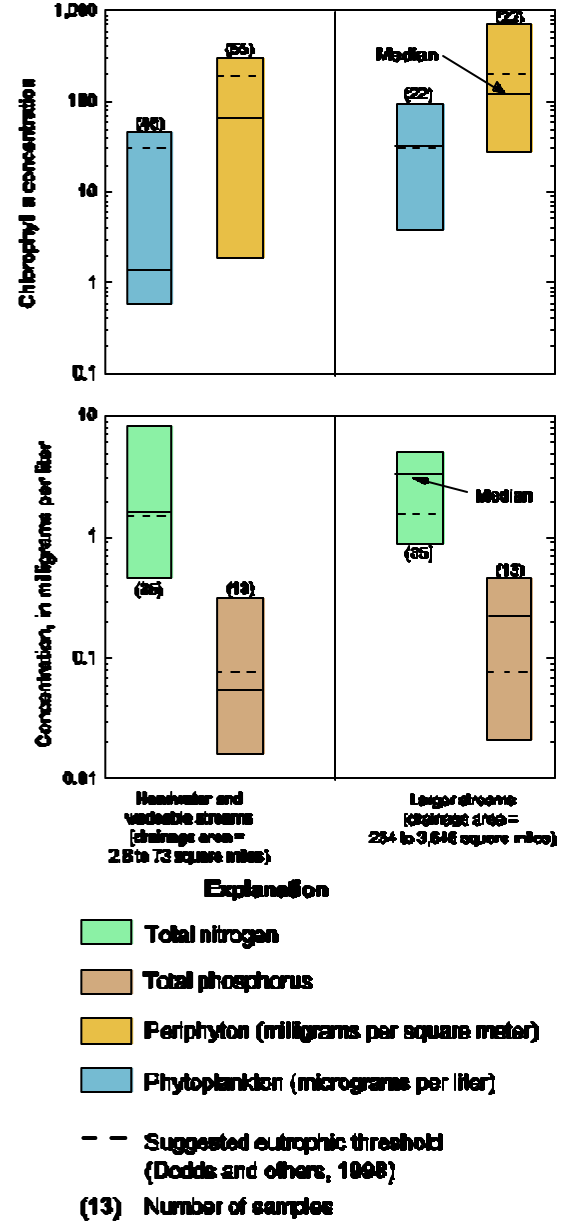


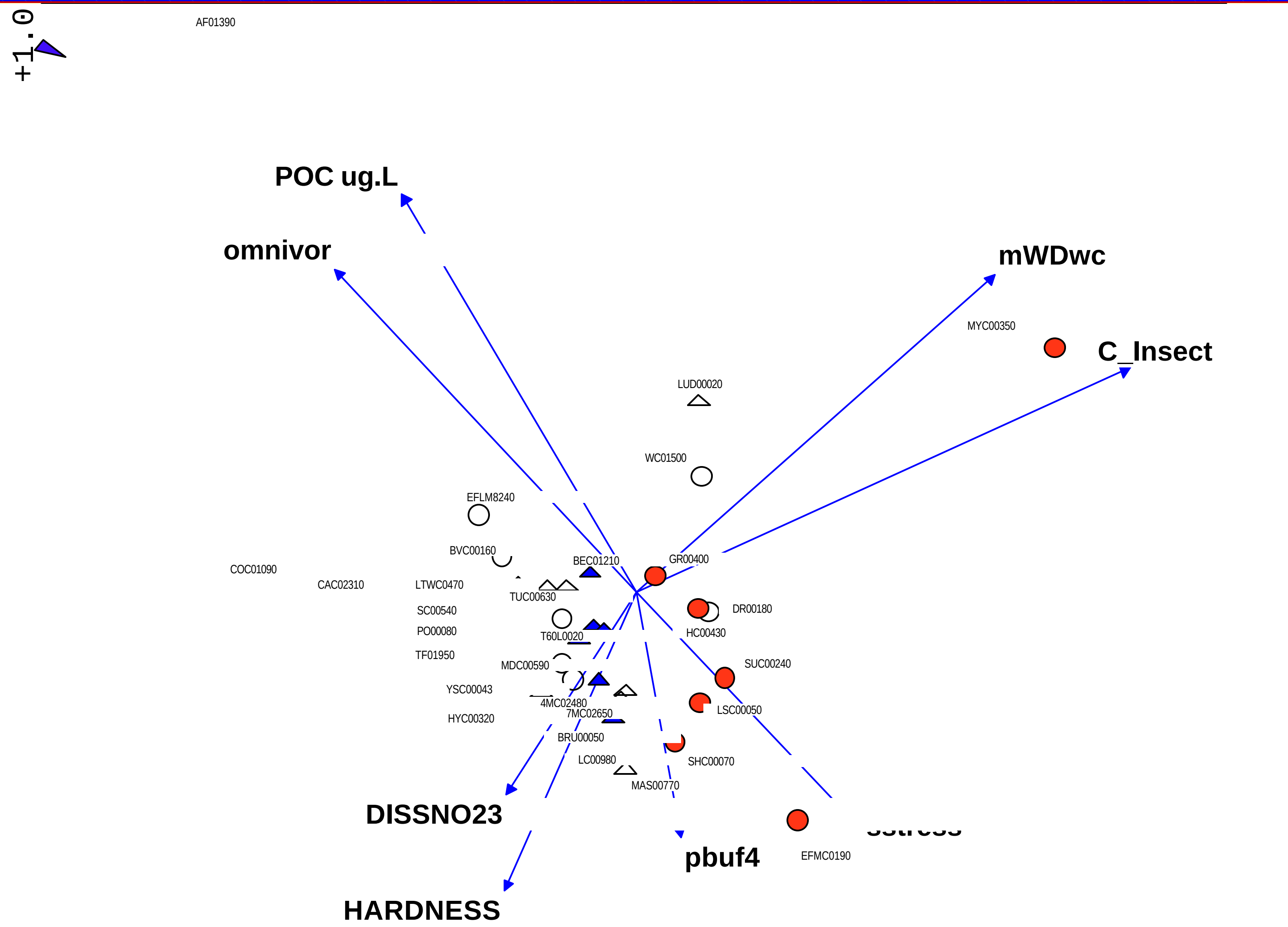
With permission from S.D. Porter who worked with David A. Peterson

Stream size can be an important factor.

Smaller drainage areas should have lower nutrients and lower algal biomass than larger streams.

Presently a tiered approach to biocriteria is being considered





+1.0
AF01390
POC ug.L
omnivor
mWDwc
MYC00350
C_Insect
LUD00020
WC01500
EFLM8240
BVC00160
COC01090
CAC02310
LTWC0470
BEC01210
GR00400
TUC00630
SC00540
DR00180
PO00080
T60L0020
HC00430
TF01950
MDC00590
SUC00240
YSC00043
4MC02480
7MC02650
LSC00050
HYC00320
BRU00050
LC00980
SHC00070
MAS00770
DISSNO23
EFMC0190
pbuf4
HARDNESS

Key variables for explaining model variance of Periphyton biomass

»	**p value = <**
• Shear stress	0.0050
• Particulate Organic Carbon	0.0275
• Mean width to depth ratio of wetted channel	0.0825
• Total Concentration of Insecticides	0.0850
• Hardness	0.1150
• Omnivorous Fish	0.1250
• Percent Forest in stream buffer area	0.1325
• Dissolved Nitrate plus Nitrite	0.1425

USGS

Develop a Disturbance Index based on form of attachment ?

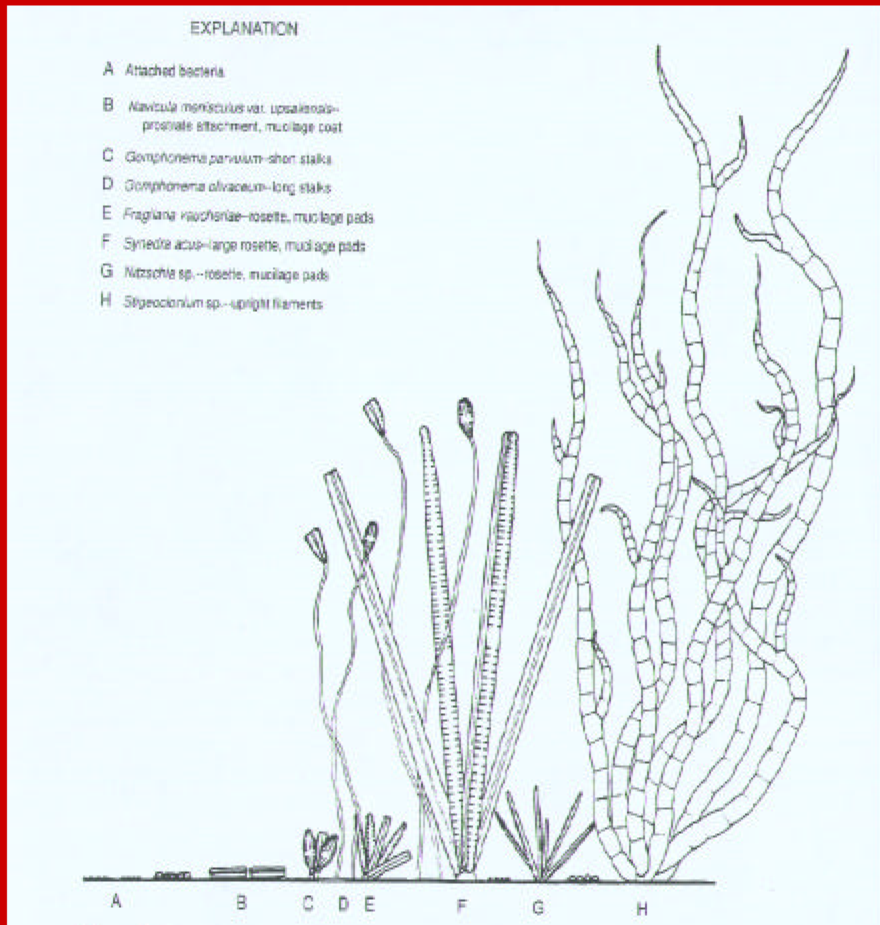
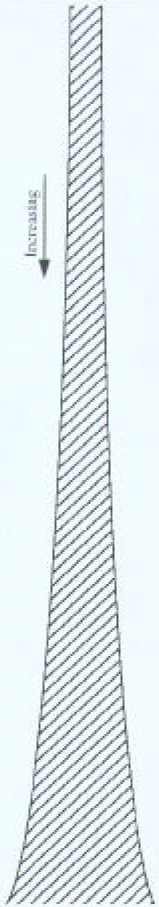
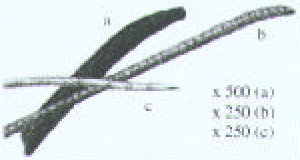
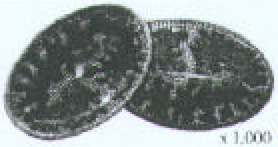
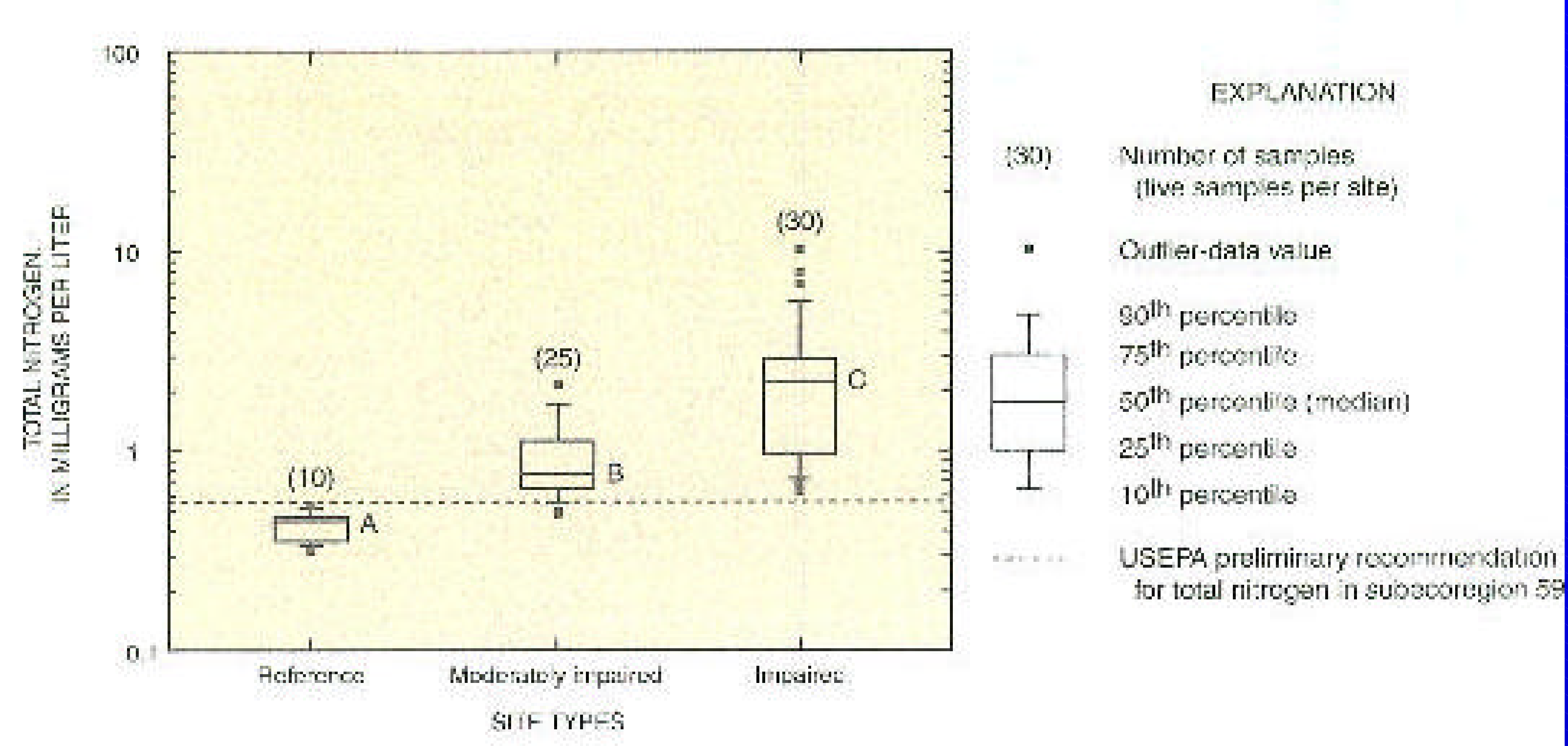


Figure 23. Range of vertical stature in the periphyton community, from attached bacteria to upright filaments (from Hoagland and others, 1982).

Form of attachment	Representative taxa	Morphology	Hydrologic resistance
Unattached single cells	*Navicula*	 x 1,500	 Increasing
Long stalks	*Gomphonema*	 x 175	
Apical pads	*Synedra*	 x 250	
Mat-forming	*Oscillatoria*	 a b c x 500 (a) x 250 (b) x 250 (c)	
Holdfasts	*Audouinella*	 x 175	
Prostrate Biofilm	*Cocconeis*	 x 1,000	

Total Nitrogen concentrations among site types in the New England Coastal Basins study area.



Riskin and others, 2003, USGS WRIR 03-4191

Chlorophyll *a* by site type and canopy cover in New England Coastal Basins

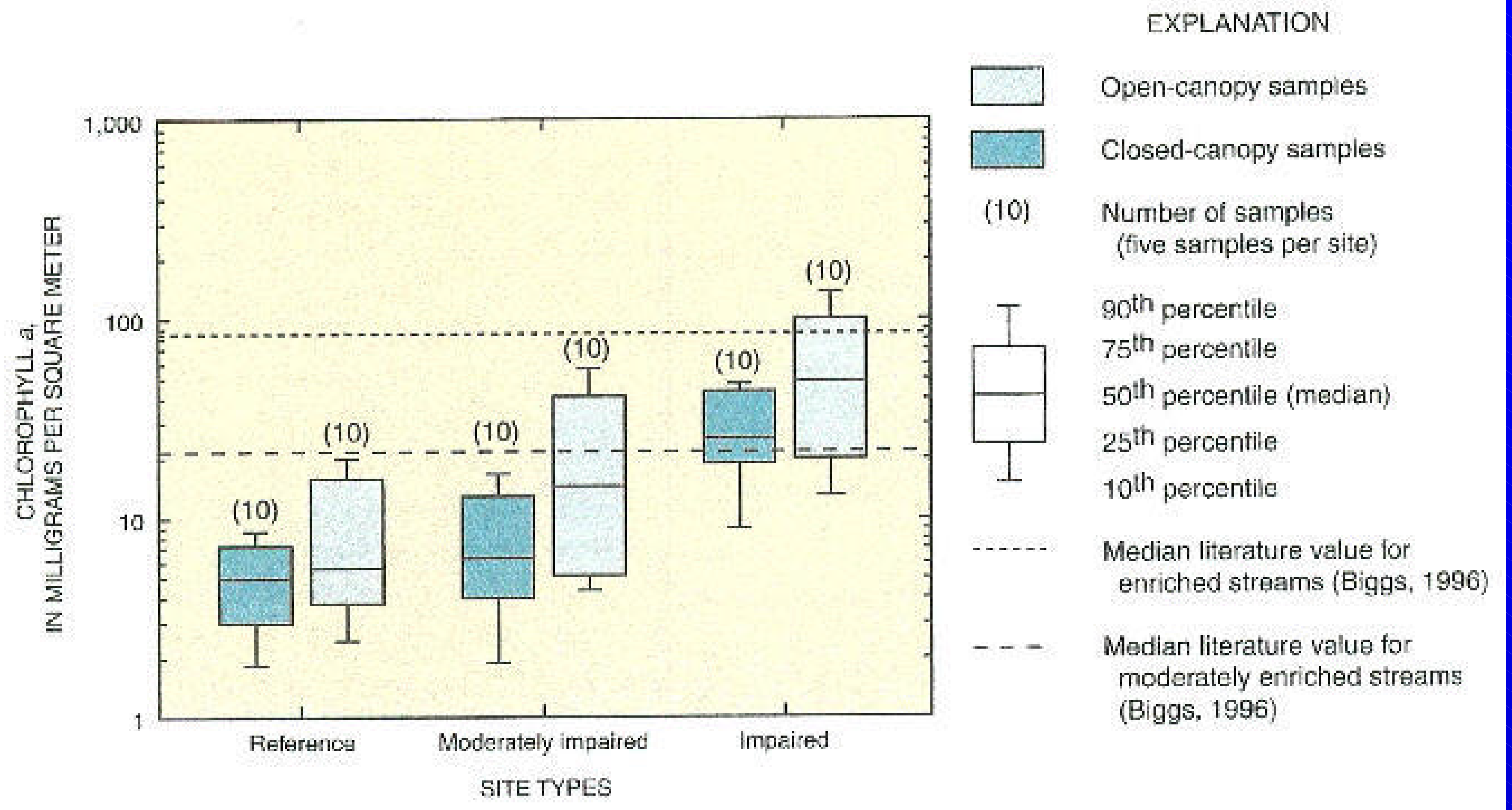


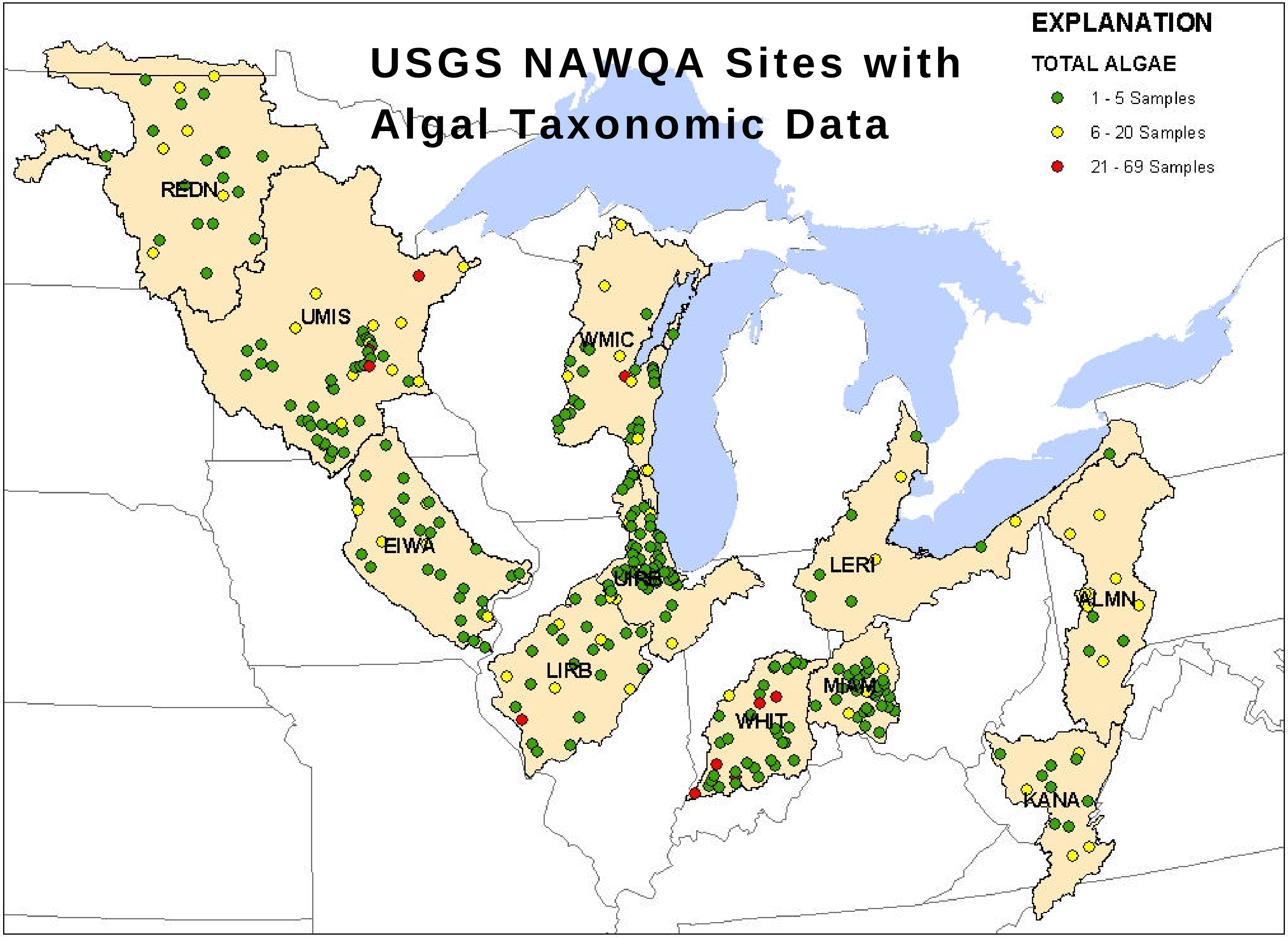
Figure 6. Chlorophyll *a* from periphyton samples among site types at the six sites with open- and closed-canopy sampling locations in the New England Coastal Basins study area.

Riskin and others, 2003, USGS WRIR 03-4191

Important Ancillary Data

- Nutrients
  - Phosphorous; total and dissolved
  - Nitrogen; NO_3, NH_4, TKN
- Light
  - Riparian shading as well as stream width
  - Instream turbidity
- Disturbance
  - Hydrologic: storm events, dam or industrial releases
  - Biotic: grazers (snails, catfish), human (recreation)

Consider a tiered approach for setting criteria to protect streams as well as rivers downstream


USGS NAWQA Sites with
Algal Taxonomic Data
EXPLANATION
TOTAL ALGAE
1 - 5 Samples
6 - 20 Samples
21 - 69 Samples
REDN
UMIS
WMIC
EIWA
UIRB
LIRB
LERI
ALMN
MIAM
WHIT
KANA

Using algae/primary producers to detect nutrient impairment

- Methods used to measure assess algal biomass/primary production
- Method comparison
- Data comparability
- Reproducibility and accuracy (QA/QC)
- Costs
- Benefits/Downfalls (i.e., is it an early indicator of nutrient enrichment?)
- Discussion on initial reactions to how well these methods support nutrient criteria development?

USGS

Measuring turbidity with Secci Disc or Light meter